CHEMISTRY

Grades 12 and 13

Teachers' Guide

(Implemented from 2017)

Department of Science
Faculty of Science and Technology
National Institute of Education

Printing and Distribution – Educational Publications Department

Chemistry

Teachers' Guide

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Message from the Hon. Minister of Education

In fulfilling the task of providing a high-quality education to the children of Sri Lanka, which is the main function of the Ministry of Education, the contribution received from the teachers is invaluable. Teachers' responsibility in producing citizens who possess the capacity to handle the challenge of the rapidly changing society is very special.

Teacher Instructional Manuals, which help teachers in facilitating the teaching-learning process and in updating syllabi based on the timely needs, are an important tool in education. If a supportive learning environment can be built in the classroom, measures being implemented by the government to accomplish the global education objectives will be successful. Ministry of Education always institutes appropriate measures to strengthen the teacher in order to achieve that objective.

I commend the teachers for the valuable service they render in creating a future generation with a balanced personality by motivating them to explore new knowledge in the bursting knowledge society, being on the basis of the value systems of the traditional wisdom. I expect active support of the teachers to help children make our motherland an oasis enabling them to keep pace with the powerful countries in the world.

I would like to pay my compliments to the National Institute of Education and the panel of external scholars for the dedication in compiling this Teacher Instructional Manual and I also commend the strong contribution made by the Educational Publications Department in publishing it.

AkilaVirajKariyawasam

Minister of Education

Message from the Director General…

With the primary objective of realizing the National Educational Goals recommended by the National Education Commission, the then prevalent content based curriculum was modernized, and the first phase of the new competency based curriculum was introduced to the eight year curriculum of the primary and secondary education in Sri Lanka in the year 2007.

The second phase of the curriculum cycle thus initiated was introduced to the education system in the year 2015 as a result of a curriculum rationalization process based on research findings and various proposals made by stakeholders.

Within this rationalization process the concepts of vertical and horizontal integration have been employed in order to build up competencies of students, from foundation level to higher levels, and to avoid repetition of subject content in various subjects respectively and furthermore, to develop a curriculum that is implementable and student friendly.

The new Teachers' Guides have been introduced with the aim of providing the teachers with necessary guidance for planning lessons, engaging students effectively in the learning teaching process, and to make Teachers' Guides help teachers to be more effective within the classroom. Further, the present Teachers' Guides have given the necessary freedom for the teachers to select quality inputs and activities in order to improve student competencies. Since the Teachers' Guides do not place greater emphasis on the subject content prescribed for the relevant grades, it is very much necessary to use these guides along with the textbooks prepared by the Educational Publications Department if, Guides are to be made more effective.

The primary objective of this rationalized new curriculum, the new Teachers' Guides, and the new prescribed texts is to transform the student population into a human resource equipped with the skills and competencies required for the world of work, through embarking upon a pattern of education which is more student centered and activity based.

I wish to make use of this opportunity to thank and express my appreciation to the members of the Council and the Academic Affairs Board of the NIE, the resource persons who contributed to compile these Teachers' Guides and other parties for their dedication in this matter.

Dr.(Mrs.) T. A. R. J. Gunasekara
Director General
National Institute of Education
Maharagama.

Foreword

Teachers are leading personalities among those who render a great service for the progression of the society. Teachers guide the children to mould their characters.

The Educational Publications Department takes measures to print and publish these Teacher Instructional Manuals to facilitate the teachers to carry out the teaching process successfully in accordance with the new syllabi to be implemented with effect from 2017. I strongly believe that this Teacher Instructional Manual, compiled by the National Institute of Education, will provide the required guidance to create a favourable learning environment for the children to learn.

This venture will achieve its success on the effort made to utilize the experience acquired by using this Teacher Instructional Manual in the teaching learning process. I bestow my gratitude on all those who dedicated themselves for this national endeavour.

W.D. Padmini Nalika
Commissioner General of Educational Publications
Educational Publications Department
Isurupaya
Battaramulla.
28.03.2018

Message from the Deputy Director General

Education from the past has been constantly changing and forging forward. In recent years, these changes have become quite rapid. The past two decades have witnessed a high surge in teaching methodologies as well as in the use of technological tools and in the field of knowledge creation.

Accordingly, the National Institute of Education is in the process of taking appropriate and timely steps with regard to the education reforms of 2015.

It is with immense pleasure that this Teachers’ Guide where the new curriculum has been planned based on a thorough study of the changes that have taken place in the global context adopted in terms of local needs based on a student-centered learning-teaching approach, is presented to you teachers who serve as the pilots of the school system.

An instructional manual of this nature is provided to you with the confidence that, you will be able to make a greater contribution using this.

There is no doubt whatsoever that this Teachers’ Guide will provide substantial support in the classroom teaching-learning process at the same time. Furthermore the teacher will have a better control of the classroom with a constructive approach in selecting modern resource materials and following the guidelines given in this book.

I trust that through the careful study of this Teachers Guide provided to you, you will act with commitment in the generation of a greatly creative set of students capable of helping Sri Lanka move socially as well as economically forward.

This Teachers’ Guide is an outcome of the expertise and unflagging commitment of a team of subject teachers and academics in the field Education.

While expressing my sincere appreciation for this task performed for the development of the education system, my heartfelt thanks go to all of you who contributed your knowledge and skills in making this document such a landmark in the field.

M.F.S.P. Jayawardhana
Deputy Director General
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Unit 01 - Atomic Structure

Competency Level 1.0 : **Uses electronic arrangements and energy transactions in determining the nature of matter**

Competency Level 1.1 : **Reviews the models of atomic structure**

No of periods : **06**

Learning Outcomes :

Student should be able to-

- write the observations after observing the demonstration of cathode rays.
- discuss the properties of cathode rays.
- describe the atom and subatomic particles.
- describes the Rutherford's model with the help of the conclusions of the gold leaf experiment.
- state the atomic number and mass number (nucleon number).
- explain the contribution of protons and neutrons to atomic nuclei to define isotopes.
- state nuclides.
- work out simple calculations using the relative atomic mass of an atom.
- appreciate the attempts made by scientists to understand nature.

Guidance for lesson planning :

- Discuss the experiments (cathode rays and Rutherford's gold foil experiment) that led to the discovery of the sub atomic particles.
- Discuss the properties of cathode rays.
- Explain the Thomson's model and Rutherford's model of the atom.
- Introduce the atomic number and the mass number with symbols.
- Introduce isotopes giving suitable examples.
- Explain how to calculate relative atomic mass of chlorine using relative atomic masses of isotopes and their abundance.
- Classify the nuclides according to their nature giving suitable examples.
- Workout simple calculations using relative atomic mass.

Relevant practical :

- Work Demonstrating properties of cathode rays.

Suggestions for Assessment:

- Assess ability to write the number of electrons, protons and neutrons for the given nuclides.

  eg: $H_2{}^{18}_{8}O$, ${}^{3}_{1}H$, ${}^{35}_{17}Cl^-$, ${}^{2}_{1}H^+$

Competency Level 1.2 : **Investigates the different types of electromagnetic radiation**

No of periods : **04**

Learning Outcomes :

Student should be able to

- state de Broglie equation.
- describe wave-particle duality of matter using de Broglie equation.
  $\lambda = \frac{h}{mV}$
- names physical quantities that describe the properties of waves with the relationships among them.
- describe the electromagnetic radiation.
- work out simple problems using
  $c = \nu\lambda$, $E = h\nu$, $\lambda = \frac{h}{mV}$ and $E = mc^2$
- name the different ranges in the electromagnetic spectrum.

Guidance for lesson planning :

- Introduce what is an electromagnetic radiation.
- Use diagrams/ video clips/ models to introduce the electric and magnetic components in electromagnetic radiation.
- Explain the dual nature of matter by using $\lambda = \frac{h}{mV}$
- Use observations of cathode ray diffraction and interference to establish dual nature and properties of electrons.
- Solve problems using the equations $E = h\upsilon$, and $C = \upsilon\lambda$, $E = mc^2$.
- Explain the electromagnetic spectrum.

Suggestions for Assessments:

- Evaluate the ability to find out different types of radiations and their common uses in day today life by giving assignments.
- Evaluate the ability to use $E = h\upsilon$ and $C = \upsilon\lambda$ by solving problems.

Competency Level 1.3 : **States the evidence for electronic energy levels of atoms**

No of periods : **09**

Learning Outcomes :
Student should be able to

- recall ionization energy of an element.
- describe successive ionization energies.
- present evidences for the presence of electrons of atoms in main energy levels and sub energy levels using graphs of successive ionization energies.
- describe the Bohr model.
- explain qualitatively the series of lines in the atomic spectrum of hydrogen using the Bohr model.
- state that energyis released or absorbed by an atom as photons/quanta.
- describe four quantum numbers.
- explain the existence of electrons in energy levels using quantum numbers up to fourth energy level.
- state that the identity of an electron in a certain atom is described by the relevant set of quantum numbers.
- state the information given by four quantum numbers.
- illustrate the shapes of s and p orbitals.

Guidance for lesson planning :

- Describe the Bohr model and existence of energy levels.
- Define the terms first ionization energy and second ionization energy.
- Guide to write common equation to represent any given ionization energy.
- Give data of ionization energies of few elements to construct graphs of successive ionization energies against the number of electrons removed.
- Explain the graphs drawn by students, as an evidence for the existence of energy levels.
- Explain the atomic spectrum of hydrogen by illustrating spectral lines of different electronic transitions.
- Introduce the names of the series of lines as Lyman, Balmer ,Paschen, Bracket and Pfund.
- Explain the main features of an atomic spectrum.
- Let the student understand that atomic spectral data can be taken as an evidence in support of the existence of energy levels in atoms.

- Review the atomic models by comparing the Thomson, Rutherford and Bohr models.
- Introduce the concept of quantization of energy and a photon using suitable analogues.
- Introduce four quantum numbers to indicate an electron in a given energy level (sub energy level).
    - Principal quantum number (*n*)
    - Azimuthal quantum number (*l*)
    - Magnetic quantum number (*m* or m_l)
    - Spin quantum number (*s* or m_s)
- Explain information given by four quantum numbers using suitable examples.
- Illustrate the shapes of sand p orbitals.

Suggestions for Assessments:

- Assess the ability to write the set of quantum numbers for a given electron in a given orbital.
- Evaluate the ability to identify relevant orbital for a given specified quantum number/ numbers.
  (Assignment of quantum numbers +1, 0, -1 for p_x, p_y, p_z orbitals is not necessary.)

Competency Level 1.4 : **States the ground state electronic configuration of isolated gaseous atoms and ions**

No of periods **: 06**

Learning Outcomes **:**

Student should be able to

- state the number of electrons in sub energy levels.
- state the principles and rules relevant to the filling up of electrons.
- write the electronic configuration of isolated gaseous atoms and ions of elements with atomic number from 1 to 54 according to the standard form.
- state the deviation from Aufbau principle using the accepted electron configuration of Pd in the 4d series.
- give examples for the existence of stable electronic configurations.

Guidance for lesson planning :

- Explain Hund's rule, Pauliexclusion principle and Aufbau principle to write the way of filling up of electrons to the energy levels.
- Let the students write electronic configurations of elements which have $Z \leq 54$.
- Write electronic configuration of cations and anions.
- Discuss the stable electronic configurations of elements using suitable examples. (s^0, s^2, p^0, p^3, p^6, d^0, d^5, d^{10})
- Show the deviation from Aufbau principle using electronic configurations of some elements in the 4d series.

Suggestions for Assessments:

- Assess ability to write correct electronic configurations for a given atoms.
- Assess ability to write electron configuration of anions and cations formed by given atoms.

Competency Level 1.5 : **Analyses the electronic configuration of elements to verify their placement in the periodic table and relates atomic properties to electronic configuration**

No of periods **: 10**

Learning Outcomes **:**

Student should be able to

- build up the periodic table on the basis of electronic configuration.
- classify the elements under s, p and d blocks in relation to the electronic configuration.
- identify elements belonging to groups 1 to 18 and periods 1to 7 relevant to the electronic configuration.
- describe the shielding effect and effective nuclear charge.
- describe the atomic radius of an element using covalent radius, van der Waals radius and metallic radius.
- compare the cationic and anionic radius with their atomic radii.
- explain the variation of covalent radius of s and p block elements across the periods and down the groups using a graph.
- explain the zigzag variation of first ionization energies of elements considering their electronic configuration.
- state electron gain energy.
- describe the variation of electron gain energy across a period and down a group.
- describe electronegativity of an element according to the Pauling scale.

Guidance for lesson planning :

- Build the periodic table with students to classify the elements according to their electronic configuration.
- Guide students to classify elements as s, p, and d block elements according to their last electron that gets filled into the respective orbital.
- Show how to identify group number of elements using their valence electrons.
- Explain the shielding effect and effective nuclear charge.
- Give the definitions of electronegativity, atomic radius, first ionization energy, electron affinity and electron gain energy.
- Describe the electronegativity of atoms according to the Pauling scale.
- Explain the variations of the above properties along a period and down a group of the periodic table.

- Explain the ability to form cations and anions across the period and down the group.
- Discuss the reasons for zig - zag variation of first ionization energy of elements along the period, considering the electronic configuration.

Suggestions for Assessments:

- Assess ability to compare atomic radius of given elements.
- Evaluate ability to identify elements by giving graphs of first ionization energies of some elements.
- Evaluate ability to explore the trends of electron gain energies of given elements.

Unit 02 : Bonding and Structure

Competency 2.0 : Relates bonding and structure to properties of matter

Competency Level 2.1 : Analyses the primary interaction of polyatomic systems as a means of determining the structure and properties of matter

No of periods : 12

Learning Outcomes :

Student should be able to

- overview chemical bonds to understand the participation of valence electrons by sharing electrons.
- explain the formation of covalent bonds by sharing electrons.
- identifiy the single bonds and multiple bonds.
- describe the rules regarding the drawing of Lewis structures.
- draw Lewis structures of covalent molecules and groups of ions.
- compare the nature of non- polar covalent bonds, polar covalent bonds and ionic bonds depending on the difference of electronegativity of the atoms involved in the bond.
- describe the polar covalent nature of bond and molecules using the concepts of polarization and dipole moment giving suitable examples.
- explain the formation of the dative-covalent bond.
- explain the formation of ionic bonds.
- explains the structure and physical properties of ionic lattice using sodium chloride.
- explain the covalent character of ionic bonds based on the polarizing power of cations and polarizability of anions.
- compare the ionic character and covalent character of compounds.
- explain the structure of the metallic bond.
- state the covalent, ionic and metallic bonding as primary interactions.

Guidance for lesson planning :

- Emphasize the participation of valence electrons to form chemical bonds by recalling the previous knowledge.
- Explain the formation of covalent bonds using suitable examples. (H_2, Cl_2, HCl, HF)
- Introduce single bonds and multiple bonds giving suitable examples (O_2, N_2)

- Explain how to draw Lewis structures of simple molecules and ions using the standard rules.
- Discuss how to divide bonds into non polar covalent, polar covalent and ionic with the use of electronegativity of atoms involved in the relevant bonds giving suitable examples.
- Describe the concept of polarization and dipole moment giving suitable examples using the values of electronegativity.
- Explain the formation of dative covalent bonds using suitable examples. (NH_4^+, H_3O^+, $NH_3.BH_3$)
- Explain the formation of ionic bonds and ionic lattice giving examples.
- Explain the properties of ionic lattices.(conductivity, melting point and solubility).
- Discuss the covalent character of ionic bonds based on the polarizing power of cations and polarizability of anions.
- Explain how metallic bonds are formed.
- Introduce the covalent, ionic and metallic bonds as primary interactions.

Suggestions for Assessments:

- Assess the ability to categorize the compounds given to them as ionic, covalent (polar, nonpolar) dative covalent and metallic.
- Assess the ability to draw Lewis structures for given species.

Competency Level 2.2 : **Analyses the shape of covalent and polar covalent molecules and simple ionic groups**

No of periods : 16

Learning Outcomes :

Student should be able to

- draw the resonance structures commonly encountered and containing up to a maximum of ten atoms, by using standard rules.
- explain using resonance the reason for the equality of bond lengths in the ozone molecule and the carbonate ion.
- explain the hybridization of atomic orbitals.
- describe howsp, sp^2 and sp^3 hybridizations take place in the central atom using suitable examples.
- state that the σ bond can be formed by the linear overlapping of s-s, s-p and p-p orbitals.
- state that the π bond can be formed by the lateral overlapping of two p orbitals.
- compare strengths of the σ bond and the π bond.
- describe the formation of sigma bonds by overlapping of hybridized orbitals.
- predict using the valence shell electron pair repulsion theory, how the pairs of electrons are oriented around the central atom (electron pair geometry) of covalent molecules and ions and thereby the shapes of the molecule/ion (molecular geometry).
- compare the bond angles of different types of molecules (exact values of bond angles will not be tested).
- construct the models of molecules to illustrate the shapes.
- describe the variation of electronegativity according to the charge, hybridization and oxidation number(qualitativelyonly).

Guidance for lesson planning :

- Introduce the concept of resonance structures.
- Explain the hybridizations sp, sp^2 andsp^3 using the electronic arrangement in the central atom of covalent molecules and polyatomic ions.
- Illustrate the formation of σ and π bonds by overlapping (linear/lateral) of atomic/hybridized orbitals.
- Explain the resonance hybrids using resonance structures in species suchas O_3 and CO_3^{2-} to show the equality of bond lengths.

- Explain the shapes of molecules using valence shell electron pair repulsion theory(showing repulsions in maximum up to six election pairs).
- Discuss how to determine approximate bond angles of different types of molecules.
- Explain how the electronegativity of the central atom varies on the charge, hybridization and oxidation number.

Relevant practical work :

- Displaying the shapes by using models

Suggestions for Assessments:

- Assess the ability to determine the shapes of given molecules and ions.
- Assess the ability to predict approximate bond angles of given molecules. (examples: PCl_3, CH_4, H_2O, NH_4^+, NO_3^-, SO_2)
- Assess the ability to compare the electronegativity of the central atom in given molecules/ions.

Competency Level 2.3 : **Analyses the secondary interactions existing in various system as a means of determining the structure and properties of matter**

No of periods : **07**

Learning Outcomes :

Student should be able to

- describe the types of secondary interactions using suitable examples.
- highlight the relationship between the nature of secondary interactions present in a substance and its physical properties.
- explain the effect of hydrogen bonds on the melting points of the elements in groups 15, 16 and 17.
- identify the importance of secondary interactions and their effect on the state.
- explain the formation of molecular lattices using given examples.
- predict the physical properties of lattice structures.

Guidance for lesson planning :

- Explain the secondary interactions giving examples for dipole – dipole interaction, hydrogen bonding, ion- dipole interaction, ion- induced dipole interaction, dipole- induced dipole interaction and London forces or dispersion interaction qualitatively.
- Discuss the importance of secondary interaction and their effects showing different physical states of matter using models or videos.
- Explain how to form different types of lattices due to secondary interactions.
- Discuss the physical properties of molecular lattice structures. ($I_2(s)$, $H_2O(s)$)

Suggestions for Assessments:

- Assess the ability to compare the boiling points and melting points of given substances.

Unit 03 : **Chemical calculations**

Competency 3.0 : **Works out chemical calculations accurately**

Competency Level 3.1 : **Determines chemical formulae using physical quantities related to atoms and molecules and works out relevant calculations using relevant data**

Number of periods : **13**

Learning Outcomes :

Student should be able to

- find the oxidation number of the constituent atoms of a given species.
- write chemical formulae and name them using IUPAC rules.
- state the common names of the chemical compounds used frequently.
- state the value of Avogadro constant (L).
- carry out calculations related to moles and Avogadro constant.
- determine the empirical formula when the percentage composition is known.
- determine the molecular formula when the empirical formula and the molar mass are known.
- determine the composition of elements when the molecular formula is given.
- review the parameters of composition (mass fraction, volume fraction, mole fraction, concentration)
- solve problems related to mass fraction, volume fraction and mole fraction.
- define concentration as the composition expressed in terms of moles of the solute per volume.
- use ppm and ppb to express the composition containing trace amounts of substances.
- calculate and express the compositions in terms of mass/volume, amount/volume (concentration).
- solve problems related to mass/volume and amount/volume.
- handle glassware such as pipette, burette, beakers, measuring cylinders and four beam balance in the laboratory.

Guidance for lesson planning :

- Explain how to assign the oxidation number of the component atoms using different chemical compounds.
- Guide the students to write chemical formulae and names for simple inorganic compounds using IUPAC rules.
- Group the students and assign them to find the common names of the frequently used chemical compounds.
- Explain the importance of the Avogadro's Constant chemical calculations, using examples.
- Guide the students to do the calculations based on moles and Avogardro Constant.
- Introduce empirical formula and molecular formula and help students to identify the difference between them using suitable examples.
- Guide the students to determine empirical formula and molecular formula using percentage compositions of compounds.
- Help students to understand parameters of composition using examples (mass fractions, volume fraction, mole fraction).
- Introduce and show that concentration can be expressed interms of mol/ volume.
- Group the students, assign suitable examples and guide them to calculate the concentrations and compositions.
- Demonstrate the proper use of laboratory glassware and allow them to practice those techniques in handling glassware.
- Guide students to handle four beam balance accurately.

Relevant practical work : Handling glassware and four beam balance.

Suggestions for Assessments:

- Assess the ability to solve different types of calculations based on concentration and the composition.

Competency Level 3.2 : **Uses different kinds of methods to balance the chemical equations**

Number of periods : **10**

Learning Outcomes :

Student should be able to

- examine the balance in a chemical equation considering the mass and charge conservation.
- balance equations using inspection method and the redox method.
- balance simple nuclear reactions.

Guidance for lesson planning :

- Assign students to balance equations by considering the mass and charge conservation.
- Show and guide how to balance equations using the inspection method.
- Guide students to balance redox reactions using oxidation number method and ion-electron half equation method.
- Guide students to balance simple nuclear reactions.

Suggestions for Assessments:

- Assess the ability to balance different types of given equations for reactions.

Competency Level 3.3 : **Carries out calculations associated with stoichiometry and titrations**

Number of periods : **14**

Learning Outcomes :

Student should be able to

- calculate quantities in chemical reactions using stoichiometry.
- explain methods of preparation of solutions and dilution.
- prepare a solution of Na_2CO_3 of known concentration.

Guidance for lesson planning :

- Explain how to do calculations relevant to the preparation of solutions by dilution of solutions.
- Assign the students to carry out calculations relevant to acid – base reactions.
- Direct students to solve different types of problems using balanced equations.

  Examples:

  i) Finding the new concentration when a given solution is diluted.
  ii) Finding the concentration of the ions in the solution obtained when two solutions which do not react with each other are mixed.
  iii) Finding the concentration of the ions in the solution obtained when two solutions which react with each other are mixed.
  iv) Finding the concentration of an acid solution of which the percentage by weight and density are given.
  v) Doing calculations relating to the preparation of aknown concentrated solution from two solutions given.
  vi) Doing calculations relating to the preparation of solutions of specified concentrations using anhydrous and hydrated solids.
  vii) Finding the mass of a precipitate formed when two solutions are mixed.
  viii) Determining the composition of each component in the mixture when two reactions occur simultaneously.
  ix) Solving problems relating to the determination of the reagent left unreacted after a reaction using another reagent.
  eg. Use of excess dilute hydrochloric acid in the determination of the amount of calcium carbonate in a sample of limestone.
  x) Solving alternative problems related to the above mentioned topics.

Relevant practical work :

Preparation of standard solution of Na_2CO_3.

Suggestions for Assessments:

- Assess the ability to solve different types of problems based on stoichiometry.

Unit 04- State of matter; Gaseous state

Competency 4.0 : **Investigates the behavior of the gaseous state of matter**

Competency Level 4.1 : **Uses organization of particles in three principal states of matter to explain their typical characteristics**

Number of periods : **02**

Learning Outcomes :

Student should be able to

- investigate the organization of particles in the principal states solid, liquid and gas.
- compare the macroscopic properties such as volume, density, shape (under the influence of gravity) and compressibility of solids, liquids and gases in relation to the arrangement of particles and their movement.

Guidance for lesson planning :

- Discuss why the macroscopic properties of solids, liquids and gases are different due to the arrangement of the particles therein.

Suggestions for Assessments:

- Assess the ability to compare the properties such as volume, density, shape and compressibility of given substances.

Competency Level 4.2 : **Uses the model of ideal gas as a means of describing the behavioural patterns of real gases**

Number of periods : 10

Learning Outcomes :

Student should be able to

- define an ideal gas.
- write the ideal gas equation and its derivatives with their terms.
- state Boyle, Charles and Avogadro laws and show the consistency of ideal gas equation.
- define the molar volume of a gas.
- solve problems related to the ideal gas equation and its derivatives.
- determine experimentally the molar volume of oxygen.
- determine the relative atomic mass of magnesium experimentally.

Guidance for lesson planning :

- Introduce the characteristic features of an ideal gas and a real gas and introduce the ideal gas equation based on them.
- Guide the students to derive equations with concentration (*C*), density (*d*) and molar mass (*M*) starting from ideal gas equation.
- Assign students to solve problems related to the ideal gas equation and its derivatives.
- Show how to derive Boyle law, Charles law and Avogadro law form the ideal gas equation.
- Guide the students to write the Boyle law, Charles law and Avogadro law in words.
- Define the molar volume of a gas.

Relevant practical work :

Experimental determination of molar volume of a gas.

Experimental determination of relative atomic mass of magnesium using molar volume of hydrogen gas.

Suggestions for Assessments:

- Assess the ability to derive Boyle ,Charles and Avogadro laws from $PV = nRT$
- Assess ability to solve different types of problems related to $PV= nRT$and its derivatives related to density, molar mass and concentration.

Competency Level 4.3 : Uses the molecular kinetic theory of gases as a means of explaining the behaviour of real gases

Number of periods : 08

Learning Outcomes :

Student should be able to

- state the assumptions of the molecular kinetic theory of gases.
- describe the factors affecting the pressure of a gas.
- write expressions for mean speed and root mean square speed.
- state the kinetic molecular equation and describe its terms.
- derive $\overline{C^2} = \frac{3RT}{M}$
- solve simple problem related to $\overline{C^2} = \frac{3RT}{M}$
- describe the information given by Maxwell - Boltzmann curves for gases.
- explain the changes of Maxwell - Boltzmann curves with temperature and molar masses.

Guidance for lesson planning :

- Introduce the assumptions made in molecular kinetic theory of gases.
- Explain the difference between the root mean square speed and mean speed.
- Introduce the kinetic molecular equation, $PV=1/3\ mN\overline{C^2}$.
- Derive $\overline{C^2} = \frac{3RT}{M}$ from kinetic molecular equation and ideal gas equation.
- Draw the Maxwell – Boltzmann curves for gases for two separate temperatures and explain the variation comparatively.
- Draw the Maxwell-Boltzmann curve for different gasses at the same temperature.

Suggestions for Assessments:

- Assess ability to calculate the mean square speed of different gases at given temperatures by using correct standard units.
- Assess ability to do simple calculations related to $PV=1/3\ mN\overline{C^2}$ for different conditions of gases.
- Assess ability to get information and compare the variation obtained from the Maxwell Boltzmann curves.

Competency Level 4.4 : **Uses Dalton's law of partial pressure to explain the behaviour of a gas mixture**

Number of periods : **06**

Learning Outcomes :

Student should be able to

- explain the term partial pressure.
- state Dalton law of partial pressures.
- derive Dalton law of partial pressures from the ideal gas equation.
- solve problems related to Dalton law of partial pressures.

Guidance for lesson planning :

- Introduce the partial pressure of a particular gas in a gaseous mixture.
- Guide the students to write the Dalton law of partial pressures in words.
- Show how to derive Dalton law of partial pressures from the ideal gas equation.
- Assign the students to solve problems related to the Dalton law of partial pressures.

Suggestions for Assessments:

- Assess ability to derive the Dalton law starting from $PV= nRT$.
- Assess ability to do different type of calculations applying Dalton law of partial pressures for a given mixture of gases.

Competency Level 4.5 : **Analyses amendments to the ideal gas equation for applying it to real gases**

Number of periods : **06**

Learning Outcomes :

Student should be able to

- define the compressibility factor.
- present graphically how this value varies with temperature in real and ideal gases.
- describe the reasons for the deviation of real gases from the behaviour of ideal gases by using assumptions of molecular kinetic theory.
- present van der Waals equation as an equation constructed to explain the deviation of real gases from the ideal behaviour.
- describe the critical temperature.
- value the idea that scientific concepts are not static but subject to continuous improvements based on facts.

Guidance for lesson planning :

- Define the compressibility factor.
- Present the variationof the compressibility factor with pressure in real gases and in an ideal gasesto describe the reasons for the variation using the assumptions of the molecular kinetic theory.
- Introduce the vander Waals equation with the corrections to the ideal gas equation.
- Guide the students to explain the deviation of real gases from the ideal behaviour.
- Explain the critical temperature.

Suggestions for Assessments:

- Assess ability to give reasons for the deviation of real gasses from ideal behaviour using graphs.

Units 05:Energetics

Competency Level 5.0 : **Predicts the stability of chemical systems and feasibility of conversions by investigating associated changes in enthalpy and entropy**

Competency Level 5.1 : **Explores concepts related to enthalpy**

Number of periods :05

Learning Outcomes :

Student should be able to

- describe the extensive and intensive properties.
- define the terms system, surrounding, boundary, closed system, open system and isolated system.
- state the standard states of pure substances and solutions.
- define the terms state of a system and a state function.
- explain the enthalpy change of a reaction.
- describe enthalpy as a function of state or thermodynamic property but not heat.
- states that the units of ΔH are given either in kJ mol^{-1} considering a unit amount of the reaction or in kJ considering the total amount of the reaction.
- calculate the enthalpy change associated with a process using $\Delta H = H(final) - H(initial)$
- calculate the enthalpy changes under standard states using $\Delta H^0 = H^0(final) - H^0(initial)$

Guidance for lesson planning :

- Explain the extensive and intensive properties using suitable examples.
- Define open system, closed system, isolated system, system boundary and surrounding.
- Present suitable examples for the different types of systems and their properties.
- State the standard states of pure substances.
- Describe enthalpy as a thermodynamic property or state function by using examples.
- Explain the standard unit for ΔH *is* $kJmol^{-1}$ since it is affected by the extent of the reaction or is reported as a differential value in kJ.
- Explain the state of a system and state functions.
- Give questions to calculate enthalpy change associated with reactions and processes using state functions.

Suggestions for Assessments:

- Assess ability to categorize the given systems as open, closed or isolated systems.
- Ask questions to assess the ability toemphasize the importance of state function and units of the enthalpy.
- Assess ability to calculate ΔH using the state functions.

Competency Level 5.2 : **Defines the enthalpy changes and calculates enthalpy changes associated with a given conversion**

Number of periods : **23**

Learning Outcomes :

Student should be able to

- calculate heat changes at constant pressure using Q = m$c\Delta T$
- explain the endothermic and exothermic reactions using energy diagrams.
- define enthalpy changes and standard enthalpy changes given in the syllabus.
- states Hess Law.
- calculate enthalpy changes using
  - enthalpy diagrams
  - thermodynamic cycles
  - only using formation enthalpies as well as only using bond dissociation enthalpies separately.
- determine experimentally the enthalpy of neutralization of acids and bases.
- state that the neutralization enthalpy of strong acids and strong bases is constant.
- state that the neutralization enthalpy of weak acid/weak base is somewhat different from that of strong acid/strong base.
- test the validity of Hess law by preparing 250 cm^3 of 1mol dm^{-3} NaCl solution , two methods.

Guidance for lesson planning :

- Explain how to calculate a heat change using $Q= mC\Delta T$.
- Explain endothermic and exothermic reactions using suitable examples and energy level diagrams.
- Guide the students to write correct equations for the enthalpy changes given in the syllabus.
- States Hess law.
- Assign students to calculate enthalpy changes using enthalpy diagrams, the thermodynamic cycles and equations applying Hess law.
- Discuss neutralization enthalpies of strong/weak acids and bases.

Relevant practical work :

- Experimental determination of the enthalpy of acid-base neutralization (NaOH and HCl , KOH and HNO_3 , NaOH and CH_3COOH, NH_4OH and HCl)
- Validation of Hess Law through experiments.

Suggestions for Assessments:

- Assess ability to do calculation using $Q = mC\Delta T$.
- Assess ability to calculate the enthalpy changes of given reactions using different methods applying Hess Law.

Competency Level 5.3 : **Calculates the lattice enthalpy or enthalpy of formation of an ionic compound using Born – Haber cycle**

Number of periods : **08**

Learning Outcomes :

Student should be able to

- define the enthalpy changes used to develop the Born Haber cycle.
- develop the Born – Haber cycle related to lattice enthalpy.
- calculate the standard lattice enthalpy using the Born – Haber cycles.
- calculate the standard lattice enthalpy using enthalpy diagrams.
- explain the variation of electron gain enthalpies of elements of second and third periods.

Guidance for lesson planning :

- Defines the standard enthalpies of sublimation, vapourization , fusion, atomization , ionization ,electron affinity and lattice.
- Explain the variation of electron affinities of the elements of second and third periods.
- Guide the students to draw Born – Haber cycles to calculate the formation and the lattice enthalpy of an ionic compound.
- Explain how to solve problems using the Born- Haber cycle.
- Explain the variation of electron gain enthalpies of elements of second and third periods.

Suggestions for Assessments:

- Assess ability to define standard enthalpy changes associated with the Born - Haber cycle.
- Assess ability to calculate the standard enthalpy of formation and lattice enthalpy using Born -Haber cycles.

Competency Level 5.4 : **Predicts the spontaneity of chemical reactions**

Number of periods : **05**

Learning Outcomes :

Student should be able to

- explain the terms entropy (S) and entropy change(ΔS) as a measurement of randomness.
- explain that the stability of the system increases with the randomness.
- state that the entropy change depends on the temperature, physical state and the arrangement of particles.
- explain Gibbs energy (G) and Gibbs energy change (ΔG).
- state that S and G are state functions.
- calculate ΔS and ΔG using
  $\Delta S = S_{(products)} - S_{(reactants)}$
  $\Delta G = G_{(products)} - G_{(reactants)}$
- explain the terms ΔG^0 and ΔS^0.
- state the relationship among ΔG, ΔH and ΔS.
- state the relationship among ΔG^0, ΔH^0 and ΔS^0.
- predict the spontaneity of a reaction or an event occurring under constant pressure and temperature using ΔG.
- state that ΔG and ΔS are reported as an integral quantities.
  [ΔG (kJ), ΔS (JK^{-1})] or per extent of a reaction ($kJmol^{-1}$).
  [ΔG (kJ mol)$^{-1}$,ΔS ($kJK^{-1}mol^{-1}$)].
- calculate the problems based on standard values ΔG^0, ΔH^0 and ΔS^0.
- forecast the feasibility of a reaction using the value of ΔG and
  $\Delta G = \Delta H - T\Delta S$

Guidance for lesson planning :

- Introduce the entropy (S) and Gibbs free energy (G) as sate functions.
- Develop the relationship among ΔG, ΔH, ΔS and ΔG^0, ΔH^0 and ΔS^0.
- Show how the ΔG value is used to predict the spontaneity of a reaction or an event under constant pressure at a given temperature.
- Assign the students to do the calculations based on ΔG, ΔS, ΔH (ΔG^0, ΔS^0 and ΔH^0) and predict the feasibility of a reaction.

Suggestions for Assessments:

- Assess ability to solve problems related to enthalpy change and entropy change using equations $\Delta G = \Delta H - T\Delta S$ and $\Delta G^0 = \Delta H^0 - T\Delta S^0$.
- Assess ability to predict the spontaneity of a process using the ΔG value.
- Assess the ability to calculate the minimum temperature required for the reaction to become spontaneous.

Unit 06 - Chemistry of s, p and d block elements

Competency 6.0 : Investigates the elements and compound of s, p and d blocks to be familiar with their properties

Competency Level 6.1 : Investigates chemical properties of elements in the *s* block

Number of periods : 10

Learning Outcomes :

Student should be able to

- describe the occurrence of s block elements and compounds.
- describe the nature of the reactions by means of balanced chemical equations of elements of the first and second groups with air/O_2, water, acids, N_2 and H_2.
- observe reactions of Na and Mg with air, oxygen, water and acids taking them as representative elements.
- compare thereactivity of the elements of group 1 and 2 by using experimental observations.
- explain that 's' block elements can function as reducing agents by forming stable cations with noble gas configuration by giving up outermost shell electrons (oxidation) which are loosely bonded to the nucleus.
- states the flame colours of the s block elements using the flame test.

Guidance for lesson planning :

- Discuss the natural forms of occurrence of Na, K, Mg and Ca in nature.
- Explains the reactions of group I and group II elements with air/O_2, water, acids, N_2 and H_2.
- Write balanced chemical equations (reaction equations) of the above reaction using Na and Mg as representative elements.
- Explains the reducing ability of s block elements considering electron configuration.

Relevant practical work:

- Comparison of the reactions of' s' block metals with air, water and acids.
- Identification of elements of compounds by the flame test(Li, Na, K, Ca, Ba, Sr)

Suggestions for Assessments:

- Assess the ability to compare the reactivity of group 1 and 2 elements by giving suitable questions.
- Evaluate the ability to write balanced chemical equations(reaction equations) for the reactions of given elements with H_2, diluted acids, O_2 and air.

Competency Level 6.2 : **Investigates the elements and compounds of p block**

Number of periods : **23**

Learning Outcomes :

Student should be able to

- describe the occurrence of p block elements and compounds compared to s block.
- describe the reactions of aluminium and aluminium oxide to show their amphoteric nature.
- describe electron deficiency of $AlCl_3$ and the formation of Al_2Cl_6.
- name three main allotropic forms of carbon as diamond, graphite and fullerenes.
- explain the structure of graphite and diamond.
- explain the melting point, lubricating ability, hardness and electrical conductivity of diamond and graphite.
- present structures of CO and CO_2 and their properties.
- present structure of H_2CO_3 and explain its acidic property.
- explain the inert nature of nitrogen using bond energy.
- write examples for different oxidation numbers of nitrogen.
- present structures of oxides and oxoacids of nitrogen.
- write balanced equations for reaction of HNO_3 with Mg, Cu, C and S.
- write reactions of ammonia as an oxidizing agent with Na and Mg.
- write reactions of ammonia as a reducing agent with Cl_2 and CuO.
- write balanced equations for thermal decomposition of ammonium salts.
- identify ammonia gas and ammonium ion experimentally using HCl, litmus and Nessler reagent.
- present information about allotropic forms of oxygen and sulphur.
- present structure of oxoacids of sulphur.
- writes reactions to explain the oxidizing ability of conc. H_2SO_4 with metals, C and S.
- describe the amphiprotic property of water using the reactions with NH_3 and HCl.
- write reactions of H_2O_2 with $H^+/KMnO_4$ and $H^+/K_2Cr_2O_7$.
- write reducing reactions of H_2O_2 with KI and Fe^{2+}.
- write oxidizing reactions of H_2S with $H^+/KMnO_4$, $H^+/K_2Cr_2O_7$, and SO_2.
- write reducing reactions of H_2S with Na and Mg.
- write oxidizing reactions of SO_2 with $H^+/KMnO_4$ and $H^+/K_2Cr_2O_7$.
- write reducing reactions of SO_2 with H_2S and Mg.
- describe physical states and colours of halogens.

- write balanced equations for the reactions of chlorine with Cu Fe and NH_3.
- write balanced equations for displacement reactions of halogens.
- compare the relative oxidation powers of the halogens.
- describe the disproportionation of chlorine and chlorate(I) ions with balanced equations.
- present structures of the oxoacids of chlorine of different oxidation states.
- compare the acidity and oxidizing ability of oxoacids of chlorine using oxidation states.
- describe giving suitable examples, the acidity of hydrogen halides in aqueous medium.
- state the properties of the noble gases giving examples - XeF_4 XeF_2, XeF_6.
- identify the anions SO_4^{2-} , SO_3^{2-} , $S_2O_3^{2-}$, S^{2-} , CO_3^{2-} using precipitation method.
- explain the solubility of the precipitates in acids based on the nature of the anions.
- identifyNO_3^- and NO_2^-using dil HCl, brown ring test and NaOH/Al.
- examine the presence of nitrogen in air using Mg.
- identify the halide ions using $AgNO_3$ / NH_3, $Pb(NO_3)_2$ and Cl_2/CCl_4.
- determine the concentration of a given thiosulphate solution using KI/KIO_3.

Guidance for lesson planning :

- Discuss the occurrence of compounds containing C,N and O naturally.
- Explain the amphoteric properties of Al and Al_2O_3 with relevant reactions.
- Describe the formation of Al_2Cl_6 using the concept of electron deficiency.
- Introduce the allotropic forms of p block elements using C, O and S as examples.
- Explain the properties and reactions of oxides of C, N and S.
- Describe the properties of acyclic acids of C, N, S and Cl.
- Explain the reactions of HNO_3 with metals and nonmetals.
- Introduce NH_3 as the hydride of N.
- Explain the reactions of NH_3 as an oxidizing/reducing agent.
- Explain the behaviour of ammonium salts.
- Explain the properties and reactions of H_2O and H_2O_2.
- Discuss the properties and reactions of H_2S, $SO_2$and H_2SO_4.
- Discuss the reactions of chlorine, as an oxidizing agent, bleaching agent and an element subject to disproportionation.
- Explain displacement reactions of chlorine.
- Compare the acidity of halogen halides using bond dissociation enthalpies.

- Recall the electronic configuration of noble gases to explain the inert nature and the ability to form oxides and fluorides of xenon.

Relevant practical work :

- Identification of ammonia gas (with litmus, HCl, Nessler reagent).
- Identifications of anions.
  (X^-, SO_4^{2-}, SO_3^{2-}, $S_2O_3^{2-}$, S^{2-}, CO_3^{2-}, NO_3^-, NO_2^-) (except F^-)
- Experimental determination of the presence of nitrogen in air
- Identification of halides.
- Standardization of a solution of thiosulphate ions using KIO_3 and KI.

Suggestions for Assessments:

- Assess the ability to explain the amphoteric nature of Al and aluminiumoxides.
- Assess the ability to write the relevant reactions of H_2S, SO_2, H_2O_2, Cl_2, HNO_3 and H_2SO_4.
- Assess the ability to distinguish given unlabeled samples of halides.

Competency Level 6.3 : **Investigates the properties of compounds and their trends associated with s and p block elements**

Number of periods : **08**

Learning outcomes :

Student should be able to

- compare experimentally the solubility of the salts of s block elements in water.
- compare experimentally the thermal stability of the nitrates, carbonates and bicarbonates of s block elements.
- explain how the acidic/ basic/ amphoteric nature of the oxides and hydroxides of s and p blocks vary along the 3rd period.
- write balanced chemical equations for reactions of hydrides and halides with water to understand the trends of hydrolysis.
- compare the hydrolyzing ability of halides of group 15 elements.
- compare the water solubility of salts of s elements experimentally.
- compare the thermal stability of nitrates and carbonates of s block elements experimentally.

Guidance for lesson planning :

- Explain through results of experiments, the variation of the solubility of salts formed by s block elements with selective anions such asNO_3^-, CO_3^{2-} ,SO_4^{2-},Cl^-,OH^-,$C_2O_4^{2-}$,PO_4^{3-},HCO_3^-,SO_3^{2-},S^{2-},CrO_4^{2-},NO_2^-.
- Explain the variation of the thermal stability of carbonates and nitrates of s elements using covalent and ionic character and using the energeticΔG.
- Guide students to write balanced chemical equations for thermal decomposition of the above compounds.
- Explain the acidic / basic/ amphoteric nature of oxides and hydroxides of 3rd period elements giving reasons.
- Guide to write relevant balanced chemical equations in order to identify their acidic, basic and amphoteric nature.
- Explain the products obtained by the reactions of water with hydrides and halides of the elements across the third period.
- Compare the hydrolyzing ability of halides of elements of group 15indicating relevant reactions.

Relevant practicals :

- Testing the solubility of salts of s block elements.
- Testing the thermal stability of nitrates and carbonates of s block elements.

Suggestions for Assessments:

- Assess the ability to identify and distinguish compounds using the solubility of salts giving suitable questions.
- Assess the ability to explain the acidic/ basic nature of aqueous solutions of given compounds.
- Assess the ability to write balanced chemical equations for the thermal decomposition of given compounds.
- Evaluate the ability to write balanced chemical equations for the reactions of water with the given compounds.

Competency Level 6.4 : **Investigates the properties of elements of 'd' block and their variation across the period**

Number of periods : **06**

Learning Outcomes :

Student should be able to

- describe the occurrence and uses of d block elements (Cu, Fe and Ti) and their compounds.
- state the variable oxidation states shown by the d block elements of the fourth period using electron configuration.
- compare the ability to form variable oxidation states of d block elements with that ofs and p block elements.
- compare electronegativity of d block elements with that of s block elements.
- compare the metallic properties of d block elements with those of s block elements.
- describe the catalytic property of d block elements.
- describe the ability of d block elements to form coloured complexes.
- identify the colours of d block complex ions experimentally.

Guidance for lesson planning :

- Introduce the elements of the first d series, with their electronic configurations.
- Explain the natural occurrence and uses of Cu, Fe and Ti and their compounds.
- Discuss the properties of d block elements (variable oxidation states, electronegativity, metallic properties, catalytic action and ability to form coloured compounds).
- Compare the above properties with s and p elements.
- Introduce the colours and structural formulae of d block complexes.

Relevant practicalwork :

- Identification of the colours of complex ions in aqueous medium.

Suggestions for Assessments:

- Evaluate the ability to express the uses of 3d elements and their compounds by giving assignments.
- Assess the ability to explain the given properties of given elements.
- Assess the ability to explain certain properties of d block elements using their electronic configurations.

Competency Level 6.5 : **Investigates the properties of compound of d block elements**

Number of periods : **08**

Learning Outcomes :

Student should be able to

- indicate acidic/basic/ amphoteric nature of oxides of chromium and manganese.
- write balanced equations for oxidation and reduction reactions of oxoanions of Cr and Mn in acidic/basic medium.
- determine the concentration of Fe^{2+} in a given sample using acidified $KMnO_4$ experimentally.
- determine the concentration of a $KMnO_4$ solution using acidified $K_2C_2O_4$ experimentally.

Guidance for lesson planning :

- Give the formula and discuss the acidic, basic and amphoteric nature of oxides of chromium and manganese.
- Instruct to write balanced chemical equations for the reactions of $Cr_2O_7^{2-}$, CrO_4^{2-} and MnO_4^- to explain their oxidizing ability.
- Demonstrate the oxidizing ability of oxoanions of Cr and Mn by using suitable reagents (eg: $C_2O_4^{2-}$,H_2O_2, H_2S,SO_2).
- Explain how to determine the concentration ofFe^{2+} in a given sample using $H^+/KMnO_4$.
- Explain how to determine the concentration of $KMnO_4$ solution using standard$K_2C_2O_4$.

Relevant practical work :

- Determination of the concentration of Fe^{2+} in a solution using a $H^+/KMnO_4$ solution.
- Determination of the concentration of a$KMnO_4$ solution using a standard $K_2C_2O_4$solution.

Suggestions for Assessments:

- Assess the ability to write the acidic / basic / amphoteric nature of given oxides of Cr or Mn.
- Assess the ability to write balanced chemical equations for the reactions of MnO_4^-, CrO_4^{2-} and$Cr_2O_7^{2-}$with given reagents to show their oxidizing ability.

Competency Level 6.6 : **Investigates properties of complex compounds of the d block**

Number of periods : **09**

Learning Outcomes :
Student should be able to

- write complexes formed by cations of Cr, Mn, Fe, Co, Ni, Cu with H_2O and Cl^-.
- name complexes containing only one type of ligands using IUPAC rules.
- write reactions of d block cations Cr^{3+}, Mn^{2+}, Fe^{2+}, Fe^{3+}, Co^{2+}, Ni^{2+}, Cu^{2+}, $Zn^{2+}$with NaOH (aq) and NH_3 (aq).
- names the colours by observing the colour of copper (II), cobalt (II) and nickel (II) salts with hydrochloric acid and ammonia.
- observe experimentally the colours relevant to the oxidation states +2, +4, +6 and +7 of manganese using redox reactions.
- identify Ni^{2+}, Fe^{2+}, Fe^{3+}, Cu^{2+} and Cr^{3+} ions in aqueous solution experimentally.

Guidance for lesson planning :

- Discuss the coloured complexes formed by d block elements.
- Explain how to name complexes containing only one type of ligands using IUPAC rules.
- Discuss the factors affecting the colour of the complex compounds with respect to the central metal ion, oxidation state and the nature of the ligands.
- Guide to observe the colours of the ions of manganese corresponding to oxidation states such as +2, +4, +6, 7 using relevant compounds.
- Explain how to identify Ni^{2+}, Fe^{3+}, Cu^{2+}, Co^{2+} and Cr^{3+} ions in aqueous solution using their ability to form coloured complexes.

Relevant practicalwork :

- Observing the colours of the complexes of Cu(II), Ni(II) and Co(II) with hydrochloric acid and ammonia.
- Observing the different colours of oxidation states +2, + 4,+6,+7 of manganese containing compounds using redox reactions.
- Identification of Ni^{2+}, Fe^{3+}, Cu^{2+} and Cr^{3+} ions using NaOH and $NH_{3.}$

Suggestions for Assessments:

- Assess the ability to identify d block cations using their complex ions.

Unit 07 - Basic concepts of organic chemistry

Competency 7.0: **Investigates the variety of organic compounds**

Competency Level 7.1 :Investigates the importance of organic chemistry as a specialfield of chemistry

Number of periods : **02**

Learning Outcomes :

Student should be able to

- state that there is a large number of natural and synthetic compounds containing carbon as the main constituent element.
- explain giving the relevant facts the ability of carbon to form a large number of compounds.
- show the importance of organic chemistry in daily life by giving examples from various fields.
- accept that organic chemistry is applied in various fields in day to day life.

Guidance for lesson planning :

- Discuss the reasons for the vast availability of organic compounds and their importance in daily life.
- Discuss the availability of varieties of organic compounds (example – fuel, cloths, detergents , medicine , food , polymers etc.)

Suggestions for Assessments:

- Assess the ability to explain the importance of organic compounds in daily life.

Competency Level 7.2 : **Investigates the variety of organic compounds in terms of the functional groups**

Number of periods : **02**

Learning Outcomes :

Student should be able to

- recognize hydrocarbons as being aliphatic or aromatic form with their structural formulae.
- identify the names and symbols of functional groups that are included in the syllabus.
- name the variety of organic compounds in terms of the functional groups present.
- name the homologous series of compounds containing each of the functional groups and present examples.

Guidance for lesson planning :

- Explain the concept of functional group for organic compounds.
- Explain the concept of a homologous series.
- List different organic compounds classifying them according to their functional groups.

Suggestions for Assessments:

- Assess the ability to identify functional groups of given compounds.

Competency Level 7.3 : **Names simple aliphatic organic compounds**

Number of periods : **06**

Learning Outcomes :

Student should be able to

- state the trivial names of the common organic compounds when the structural formula is given.
- recognize the need for a standard nomenclature.
- name the given organic compounds which are structurally within the limit stated in the syllabus, using the IUPAC rules.
- draw the structural formula of a compound when the IUPAC name is stated.

Guidance for lesson planning :

- Give some trivial names of common organic compounds.
- Introduce the nomenclature of aliphatic saturated and unsaturated hydrocarbons.
- Discuss methods for numbering the main carbon chain to indicate the position of substituent groups.
- Introduce the priority order for functional groups and the use of suffixes and prefixes.

Suggestions for Assessments:

- Assess the ability to name given compounds according to IUPAC nomenclature and the ability to write the structure of compounds for given IUPAC names.

Competency Level 7.4 : **Investigates the different possible arrangements of atoms in molecules having the same molecular formula**

Number of periods : **07**

Learning Outcomes :

Student should be able to

- draw all the possible structural formulae for a given molecular formula.
- explain the term isomerism.
- classify the given structures for given molecular formulae as chain, position and functional group isomers.
- state the requirements to be satisfied to exhibit geometrical and optical isomerism.
- recognize structural formulae of compounds that can exist as enantiomers and dioastereomers.
- summarize all type of isomerism.

Guidance for lesson planning :

- Explain isomerism as the existence of different compounds having the same molecular formula.
- Explain the types of isomers using suitable examples to show
    - constitutional isomers (chain/ position/ functional group)
    - Stereoisomers (diasteriomers/ enantiomers)
- Discuss the requirements to exhibit geometrical (cis- trans) isomerism and optical isomerism.

Suggestions for Assessments:

- Assess ability to write structures of all possible isomers that can exist for a given molecular formula.
- Assess the ability to identify the type of isomerism exhibited by a given set of compounds.

Unit 8 - Hydrocarbons and halohydrocarbons

Competency 8.0: Investigates the relationship between structure and properties of hydrocarbons and halohydrocarbons

Competency Level 8.1.: **Investigates the structure, physical properties and nature of bonding in aliphatic hydrocarbons (only acyclic aliphatic compounds are considered)**

Number of periods : **05**

Learning Outcomes :

Student should be able to

- describe the nature of the bonds in alkanes, alkenes, and alkynes using suitable examples.
- explain the variation of physical properties along the homologous series of alkanes, alkenes and alkynes.
- relate the geometrical shapes of the simple alkanes, alkenes and alkynes to the hybridization of carbon atoms.

Guidance for lesson planning :

- Describe alkanes, alkenes and alkynes writing their relevant homologous series using common general formulae.
- Introduce alkanes, alkenes and alkynes using sp^3, sp^2, and sp hybridization and their relevant geometrical shapes.
- Discuss the variation of physical properties such as melting point, boiling point and solubility by using their structures and relevant intermolecular attraction.
- Give an opportunity to make models of hydrocarbons illustrating “pi” and “sigma” bonds using available materials.

Suggestions for Assessments:

- Assess the ability to explain the variation in melting points and boiling points of compounds on the basis of intermolecular forces.
- Assess the ability to relate the shapes of molecules to the hybridization of the carbon atoms in the molecules.

Competency Level 8.2. : **Investigates and compares the chemical reactions of alkanes, alkenes an alkynes in terms of their structures**

Number of periods : **14**

Learning Outcomes :

Student should be able to

- explain the non reactivity of alkanes with polar reagents in terms of the non poloar nature of the C - C and C-H bonds.
- explain the mechanism of the free radical chlorination of methane.
- explain the tendency of alkenes to undergo electrophilic addition reactions in terms of their unsaturation and electron rich nature.
- write the mechanism of the reaction of hydrogen halides with alkenes.
- identify carbocations as reactive intermediates in the addition of hydrogen halides to alkenes.
- compare the relative stabilities of primary, secondary and tertiary carbocations.
- recognize that the direction of addition of hydrogen halides to alkenes is determined by the relative stability of the carbocation that can be formed as an intermidiate.
- recognize that the reaction of bromine with alkene is also an electrophilic addition due to the polarization of the bromine molecule during the reaction leading to the initial addition of Br^+.
- write the mechanism of the reaction between alkenes and bromine.
- write the final product obtained by the reaction between alkenes and dilute sulphuric acid followed by hydrolysis.
- write the product of catalytic hydrogenation of alkenes.
- write the product formed by the reactions of alkenes with alkaline potassium permanganate indicating their colour changes.
- explain the tendency for alkynes to undergo electrophilic addition reactions in terms of their unsaturation and electron rich nature.
- write the electrophilic addition reactions of alkynes with reagents Br_2, HX, dilute H_2SO_4 / Hg^{2+}.
- write the reactions of alkynes with H_2 in the presence of Ni/Pt/Pd.
- write the product obtained by partial hydrogenation of alkynes in the presence of Pd/$BaSO_4$/quinoline.
- recognize that the acidity of terminal hydrogen of an alkyne due to the state of hybridization of the carbon atom and that this hydrogen can be replaced by metals.

Guidance for lesson planning :

- Discuss the saturated nature of alkanes and unsaturated nature of alkenes and alkynes.
- Explain the relative non reactivity of alkanes to polar reagents compared to alkenes and alkynes.
- Discuss the reaction of methane with chlorine via free radical mechanism.
- Introduce the terms mechanism, hemolytic cleavage, heterolytic cleavage and free radical chain reactions.
- Discuss the reactive intermediates in the addition of hydrogen halides to alkenes and the relative stability of primary, secondary and tertiary carobocations.
- Explain that the characteristic reactions of alkenes and alkynes are electrophilic addition reactions.
- Explain the acidic nature of alkynes with terminal hydrogen atoms.

Relevant practicalwork :

- Observing reactions of alkenes and alkynes with alkaline $KMnO_4$ and bromine water.
- Observing reactions of terminal alkynes with ammonical silver nitrate and ammonical cuprous chloride.

Suggestions for Assessments:

- Assess the ability to predict the products of reactions of alkanes, alkenes and alkynes with specified reagents.
- Assess the ability to write the reaction mechanisms of alkanes, alkenes and alkynes relevant to the syllabus.

Competency Level 8.3. **: Investigates the nature of bonding in benzene**

Number of periods **:03**

Learning Outcomes **:**

Student should be able to

- give reasons why the structure for benzene first presented by Kekule does not explain all the properties of benzene.
- explain the structure and the stability of benzene using hybridization of carbon atoms and delocalization of electrons.
- present evidences in support of the true structure of benzene.

Guidance for lesson planning :

- Ask the students to draw a possible structures for the molecular formula $C_6H_{6.}$
- Stress the fact that in these structures there are single bonds and multiple bonds and therefore they should answer the test for unsaturation, which benzene does not.
- Discuss the 'Kelule' structure of benzene using hybridization.
- Explain the actual structure of benzene using resonance concept based on the delocalization of electrons.
- Compare the stability of benzene using theoretical values such as hydrogenation enthalpies.
- Explain, that it is convenient to use the Kekule structure to represent benzene when writing reaction mechanisms.

Suggestions for Assessments:

- Assess the ability to draw the enthalpy diagram and calculate the stabilization energy of benzene using the given enthalpy values.
- Assess the ability to draw resonance structures for benzene.

Competency Level 8.4. : **Analyses the stability of benzene in terms of its characteristic reactions**

Number of periods : **07**

Learning Outcomes :

Student should be able to

- show using suitable examples the tendency of benzene to undergo substitution reactions rather than addition reactions.
- describe the electrophilic substitution reactions as characteristic reactions of benzene using the mechanisms of nitration, alkylation, acylation and halogenation.
- compare the reactions of benzene with those of alkanes, alkenes and alkynes.
- describe the increase in the tendency to undergo oxidation of alkyl groups and acyl groups when they are attached to benzene.

Guidance for lesson planning :

- Explain the preference for electrophilic substitution reaction of benzene using alkylation, acylation, nitration and halogenations reactions over addition reactions.
- Discuss the relevant mechanisms for nitration, alkylation, acylation and halogenations reactions.
- Discuss the resistance of benzene to oxidation and hydrogenation due to the resonance stability.
- Discuss the catalytic addition of hydrogen to benzene.
- Explain the oxidation of alkylbenzenes and acylbenzenes to carboxylic acid by strong oxidizing agents.

Suggestions for Assessments:

- Assess the ability to explain the mechanisms of electrophilic substitution reactions of benzene.

Competency Level 8.5. **: Recognizes the directing ability of substituent group of mono - substituted benzene**

Number of periods : 05

Learning Outcomes :

Student should be able to

- identify the substituent groups of mono- substituted benzene as ortho, para or meta directing groups.
- state the position to which a second substituent group attaches in a mono-substituted benzene on the basis of the directing property of the first substituted group.

Guidance for lesson planning :

- Explain the terms "ortho" ,"para" and "meta"with reference to mono-substituted benzene.
- Discuss the " ortho" ,"para" and "meta" directing ability of a substituent when mono - substituted benzene undergoes electrophilic substitution reactions.

Suggestions for Assessments:

- Assess the abilitytopredict the products obtained from mono - substituted benzene by electrophilic substitution reactions.

Competency Level 8.6. : Investigates the structure and polar nature of C- X bond and reactions of alkyl halides

Number of periods : 09

Learning Outcomes :

Student should be able to

- classify alkyl halides as primary, secondary and tertiary.
- relate the tendency of alkyl halides to undergo nucleophilic substitution reactions with the polar nature of the C – X bond.
- recognize that nucleophiles can act as bases.
- explain the non reactivity of aryl halides and vinyl halides (halogens attached to sp^2 carbon atoms).
- describe the preparation and the properties of Grignard reagent.
- compare the polarity of the C- Mg with that of C-X bond and recognizes that their polarities are reversed.
- recognize that due to polarization of the C-Mg bond, the C attached to Mg in a Grignard reagent can act as the base as well as a nucleophile.
- write the product obtained by the reaction of Grignard reagent with a proton donor given in the syllabus.

Guidance for lesson planning :

- Explain the classification of alkyl halides as primary, secondary and tertiary.
- Explain the physical properties such as melting point , boiling point and solubilityof alkyl halides.
- Discuss the tendency of alkyl halides to undergo nucleophilic substitution reactions due to the polar nature of C – X bond and explain that elimination can be a competing reaction.
- Discuss the non reactivity of aryl halides and vinyl halides towards nucleophilic substitution.
- Explain the preparation of Grignard reagent and reactions of Grignard reagent with proton donors.
- Explain the nucleophilic nature and basic nature of the alkyl group in Grignard reagent.

Suggestions for Assessments:

- Assess the abilityto write all possible structures of alkyl halides for a given molecular formulae and classify them as primary, secondary and tertiary halides.
- Assess the ability to predict the products of the reactions of alkyl halides with specified nucleophiles.

Competency Level 8.7. : **Analyses the nucleophilic substitution reactions of alkyl halides in terms of the rate of bond making and bond breaking steps**

Number of periods : 03

Learning Outcomes :

Student should be able to

- recognize that there are two possible pathways for the nucleopilic substitution reactions of alkyl halides.
- describe the nucleophilic substitution reaction of alkyl halides as a one step reaction when bond breaking and bond making take place simultaneously.
- describe the nucleophilic substitution reaction of alkyl halides as a two step reaction when the formation of the new bond takes place after the breaking of the bond.

Guidance for lesson planning :

- Introduce that there are two possible pathways for the nuleophilic substitution reaction of alkyl halides, based on the time interval between the bond breaking and bond making steps.
- Discuss the reactions as one step reactions and as two steps reactions using suitable examples.
- Discuss the tendency of tertiary halides to undergo a two step mechanism and the primary halides to undergo one step mechanism based on the stability of the intermediate carbocation formed.

Suggestions for Assessments:

- Assess the ability to explain one step and two step reactions of alkyl halides using suitable examples.

Unit -09 :- Oxygen containing organic compounds

Competency 9.0 : Investigates the relationship between the structure and properties of oxygen containing organic compounds

Competency Level 9.1 : Investigates the structure, polar nature of carbon-oxygen bond and oxygen-hydrogen bond and reactions of alcohols

Number of periods : 08

Learning Outcomes :

Student should be able to

- classify alcohols as primary, secondary and tertiary.
- describe the polar nature of the O- H bond and C- O bond.
- relate the physical properties of alcohols with their ability to form hydrogen bonds.
- recognize that alcohols undergo reactions in two different ways by the cleavage of the O-H bond and the cleavage of the C-O bond.
- explain nucleophilic substitution reactions of alcohols with HBr, HI, PCl_3/PBr_3, PCl_5 due to the cleavage of C - O bonds.
- write the product obtained by the reactions of alcohols with conc.H_2SO_4,Al_2O_3 as dehydrating agents.
- relate the ease of formation of carbocation from alcohols in the presence of acids to their primary, secondary and tertiary nature.
- recognize that primary, secondary and tertiary alcohols behave differently when reacted with different oxidizing agents.
- record the properties of alcohols by examining them.

Guidance for lesson planning :

- Classify alcohols as primary, secondary and tertiary using number of alkyl groups attached to "C" with “OH”group.
- Explain the variation of physical properties of alcohols such as boiling point, melting point and solubility using intermolecular forces and their molar mass.
- Describe the reactions involving cleavage of the O-H bond .
- Describe the reactions involving cleavage of the C- O bond .
- Discuss the reactions with $ZnCl_2$, and conc.HCl (Lucas test) to distinguish primary, secondary andtertiary alcohols considering relative stability of the carbocation formed.
- Discuss the elimination reaction with conc.H_2SO_4 or Al_2O_3 to form alkenes.
- Explain oxidation reactions of alcohols.

Relevant practical work:

Testing properties of alcohols

Suggestions for Assessments:

- Assess the ability to write all possible structures of alcohols for a given molecular formula.
- Assess the ability to predict the products of the reactions of alcohols with specified reagents.

Competency Level 9.2 : **Analyse the reactions of phenol in terms of its C-O bond and O-H bond**

Number of periods : 04

Learning Outcomes :

Student should be able to

- explain why phenols are more acidic than alcohols.
- explain why phenols do not undergo nucleophilic substitution reactions undergone by alcohols.
- state the reactions of phenol with Na and NaOH.
- record the properties of phenol by simple tests.

Guidance for lesson planning :

- Explain the acidity of phenol by considering the resonance stabilization of the phenate ion.
- Explain the non reactivity of phenols under conditions where alcohols undergo neucleophilic substitution reactions.
- Discuss the physical properties of phenol using hydrogen bonds and London forces.
- Discuss the acidic nature of phenol using the reactions with Na and NaOH.

Relevant practical work : Testing the properties of phenols

Suggestions for Assessments:

- Assess the ability to compare higher acidity of phenol compared to alcohols.

Competency Level 9.3 : **Investigates the effect of the –OH group on the reactivity of the benzene ring in phenol**

Number of periods **: 02**

Learning Outcomes **:**

Student should be able to

- recognize that in the substitution reactions of phenol, the substituent gets attached to the ortho (2, 6) and para (4) positions relative to the –OH group.
- explain why the aromatic ring of phenol is more reactive towards electrophiles than benzene itself.

Guidance for lesson planning :

- Discuss the substitution reactions nitration and bromination of phenol explaining ortho – para influence of the –OH group.
- Compare the reactivity of phenol with benzene using resonance structures.

Suggestions for Assessments:

- Evaluate the ability to explain substitution reactions of phenol with given reagents.

Competency Level 9.4 : **Investigates the polar nature and unsaturated nature of $\rangle C = O$ bond in aldehyes and ketones as exemplified by their reactions**

Number of periods : **16**

Learning Outcomes :

Student should be able to

- explain the unsaturated nature of the carbonyl group.
- explain nucleophilic addition reactions as the characteristic reactions of aldehydes and ketones.
- explain the mechanism of nucleophilic addition reactions of aldehyde and ketones with Grignard reagents and HCN.
- recognize that the reaction of aldehydes and ketones with 2,4-dinitrophenylhydrazine is representative of the reaction of the $-NH_2$ group with the >C=O group.
- show the reactivity of carbonyl compounds containing α - H using suitable examples.
- recognize that aldehydes and ketones are reduced to alcohols by reducing agents.
- recognize that aldehydes are more easily oxidized than ketones.
- distinguish between aldehydes and ketones using relevant tests.

Guidance for lesson planning :

- Discuss the polarity of the carbony l group in aldehydes and ketones and explain that nucleophilic addition reactions are the characteristic reactions of aldehydes and ketones.
- Explain the reduction of aldehydes and ketones by $LiAlH_4$ and $NaBH_4$followed by hydrolysis using suitable examples.
- Discuss the ease of the oxidation of aldehydes compared to ketones.
- Discuss the effect of carbonyl group on the acidity of the alpha carbon.

Relevant practical work : Tests for aldehydes and ketones

Suggestions for Assessments:

- Assess the ability to predict the products of the reactions of carbonyl compoundswith specified reagents.
- Assessthe ability to explain nucleophilic addition reactions of aldehydes and ketones.

Competency Level 9.5 : **Compares the structure and properties of carboxylic acids with the other oxygen containing organic compounds**

Number of periods :10

Learning Outcomes :

Student should be able to

- relate the physical properties of carboxylic acids to their structure.
- recognize that the carboxylic acids contain a carbonyl group (> C = O).
- compare the acidic properties of carboxylic acids, alcohols and phenol using the reactions with Na, NaOH , Na_2CO_3 and $NaHCO_3$.
- recognize that when reacting with nucleophiles, carboxylic acids give substitution reactions while aldehydes and ketones give addition reactions.
- test the properties and reactions of carboxylic acids .

Guidance for lesson planning :

- Explain the higher acidity of carboxylic acids compared to phenols and alcohols.
- Discuss the reactions of carboxylic acids involving cleavage of the C-OH bond.
- Discuss the reduction reactions of carboxylic acid.

Relevant practical work :

Testing some properties carboxylic acid, (acidity, reducing ability, esterification)

Suggestions for Assessments:

- Assess the ability to compare acidity of carboxylic acids with other organic compounds.
- Assess the ability to write the correct variation of the acidity of given organic compounds.

Competency Level 9.6 : Investigates the characteristic reactions of acid derivatives

Number of periods : 06

Learning Outcomes :

Student should be able to

- recognize that the characteristic reactions of the acid derivatives are nucleophilic substitution reactions.
- write examples for the characteristic reactions of acid chlorides.
- write examples for the characteristic reactions of esters.
- write examples for the characteristic reactions of amides.
- recognize that all the reactions of acid derivatives involve and attack by a nucleophile on the carbonyl carbon.
- write the mechanism for the reaction between acid chloride and sodium hydroxide.

Guidance for lesson planning :

- Introduce the relevant structures for acid chlorides, esters and amides as carboxylic acid derivatives using suitable examples.
- Explain that the first step in all the reactions of acid derivatives is an attack by a nucleophile on the carbon atom of the carbonyl group.
- Discuss the reduction of amides and esters.

Suggestions for Assessments:

- Evaluate the ability to write relevant products formed by the given reagents/ reactions of acid derivatives.
- Assess the ability to do the given conversions using the above reactions.

Unit 10 : Nitrogen containing organic compounds

Competency 10 .0 : **Investigates the relationship between structure and properties of nitrogen containing organic compounds**

Competency Level 10.1 : **Analyses amines and aniline in terms of their characteristic reactions and properties**

Number of periods : **08**

Learning Outcomes :

Student should be able to

- classify the types of amines as primary, secondary and tertiary.
- write the reactions of primary amines with the reagents given in the syllabus.
- apply the knowledge of given reactions in conversions relating to amines and other functional groups given in the syllabus.
- explain the higher reactivity of aniline when compared to benzene towards electrophilic substitution.
- write the reactions of aniline with bromine.

Guidance for lesson planning :

- Explain the classification of amines as primary, secondary and tertiary considering the number of alkyl groups attached to nitrogen.
- Introduce aniline as an aromatic amine.
- Discuss the reactions of amines where they act as nucleophiles.
- Discuss the reactions of amines with nitrous acid.
- Explain the reaction of aniline with bromine.

Suggestions for Assessments:

- Assess the ability to classify the given amines as primary, secondary and tertiary.
- Assess the ability to do simple organic conversions related to the reactions of amines.

Competency Level 10.2 : **Compares and contrasts the basicity of amines with other organic compounds**

Number of periods : 02

Learning Outcomes :

Student should be able to

- compare the basicity of primary amines with that of alcohols, aniline and primary amides in terms of the relative availability of the lone pair of electrons on the N atom.

Guidance for lesson planning :

- Explain the basicity of amines due to the donating ability of the lone pair of electrons on the N atom.
- Compare the basicity of amines with alcohols.
- Compare the basicity of primary aliphatic amines with that of aniline.
- Compare the basicity of amines with amides.

Suggestions for Assessments:

- Assess the ability to compare the basicity of amines with alcohols, aniline and NH_3.
- Evaluate the ability to explain the basicity of given compounds containing nitrogen.

Competency Level 10.3 : Investigation the reactions of diazonium salts

Number of periods : 04

Learning Outcomes :

Student should be able to

- describe the preparation of diazonium salt.
- write down the reactions of diazonium salts with water, H_3PO_2, CuCl, CuCN, CuBr and KI.
- recognize that the $N \equiv N^+$ group can be easily replaced by various other groups as N_2 is a good leaving group.
- recognize that the $N \equiv N^+$ group can act as an electrophile.
- test for aniline using diazonium salt and record observations.

Guidance for lesson planning :

- Explain the method of preparation of diazonium salt with the specified temperature and relevant conditions.
- Using relevant equations discuss the reactions of diazonium salts with H_2O, H_3PO_2, CuCl, CuBr, CuCN and KI Explain the ability of diazonium salts to act as an electrophile.

Relevant practical work :Tests for aniline.

Suggestions for Assessments:

- Assess the ability to write relevant products for the given reactions related to diazonium salt.

Unit.11 : Chemical Kinetics

Competency 11.0: **Uses the principles of chemical kinetics in determining the rate of chemical reaction and in controlling the rate of reactions**

Competency Level 11.1 : **Introduces reaction rate and determines the factors affecting the rate of chemical reactions**

Number of periods : **06**

Learning Outcomes :

Student should be able to

- provide examples for chemical reactions taking place at various rates and compare the rates of different reactions.
- state the factors affecting the rate of a reaction - temperature, concentration, pressure, physical nature (surface area of reactants), catalysts.
- generalize a chemical reaction as aA + bB → cC + dD
- state that the change in the concentration of a substance is the fundamental factor in measuring the rate of a reaction.
- define rate of reaction as rate with respect to the change of concentration of the reactant A as $\left(-\frac{\Delta C_A}{\Delta t}\right)$ or rate with respect to the change of concentration of the product D as $\left(\frac{\Delta C_D}{\Delta t}\right)$.
- express that in a given reaction, the rate of removal of each reactant and rate of formation of each product are not equal.
- state that the rate of removal of a reactant or formation of a product depends on the stoichiometric coefficients of the respective substances.
- state accordingly that the generalized rate of a reaction

  $= -\frac{1}{a}\left(\frac{\Delta C_A}{\Delta t}\right) = \frac{1}{d}\left(\frac{\Delta C_D}{\Delta t}\right)$.

- state that for any type of change, rate is the change of concentration per unit time.
- illustrate with examples that time taken for a given constant change can be used in rate measurements(rate α 1/t).
- express that properties (colour intensity, turbidity etc.) which depend on the amount of a substance or concentration can also be used to compare rates.
- provide examples for slow reactions where time can be easily measured for the determination of rates.

Guidance for lesson planning :

- Compare the rates of different reactions providing suitable examples.
- Describe the factors that can affect the reaction rate.
  (temperature , concentration/pressure , physical nature of a reactant , catalysts)
- Define rate of a reaction in terms of reactants and products.

  $aA + bB \longrightarrow cC + dD$

  rate of the reaction = $-\left(\frac{\Delta C_A}{\Delta t}\right)$or rate of the reaction $= \left(\frac{\Delta C_D}{\Delta t}\right)$

  (rate of consumption of reactant) (rate of formation of product)
- Emphasize that the rate of removal of each reactant and rate of formation of each product are not equal.
- State that the rate of removal of a reactant or formation of a product depends on the stoichiometric co-efficient of the relevant substances.
- State the comparison of the rate of formation of products and rate of removal of reactant for a general reaction as ,

  $-\frac{1}{a}\left(\frac{\Delta C_A}{\Delta t}\right) = -\frac{1}{b}\left(\frac{\Delta C_B}{\Delta t}\right) = \frac{1}{c}\left(\frac{\Delta C_c}{\Delta t}\right) = \frac{1}{d}\left(\frac{\Delta C_D}{\Delta t}\right)$
- Introduce the rate of a reaction as the change of concentration of any species per unit time for any type of a reaction.
- Discuss the properties that can be used to measure the reaction rate as colour ,purity, turbidity ,gas evolution etc.

Suggestions for Assessments:

- Assess the ability to compare reaction rates of each species for a given reaction when rate of formation/consumption of a one species is given.
- Assess the ability to calculate the rate of reaction using $\left(\frac{\Delta C}{\Delta t}\right)$ when concentrations and relevant times are given.
- Evaluate the ability to give the possible methods of measuring reaction rates for a given reaction.

Competency Level 11.2 : **Uses molecular kinetic theory to explain the effect of factors affecting the rate of chemical reactions.**

Number of periods **: 06**

Learning Outcomes **:**

Student should be able to

- draw energy diagrams for a single step reactions.
- define the term activation energy.
- list the requirements essential for a reaction to occur.
- state that when temperature increases, kinetic energy of molecules is also increased.
- draw the simplified form of Boltzmann distribution curve for gaseous molecules at two different temperatures and compare the distrbution of kinetic energy of molecules at different temperatures.
- explain the increase in rate of a reaction with temperature in terms of the increase of kinetic energy of molecules and thereby the number of effective collisions.
- explain the increase in the number of collisions per unit volume per unit time using the concept of concentration.
- state that collisions having appropriate orientation is proportional to the total number of collisions.

Guidance for lesson planning :

- Define the term activation energy of a reaction.
- Explain how to draw an energy diagrams for a single step reactions.
- Describe the basic requirements for occurrence of a reaction according to collision theory.
- Draw the Boltzmann distribution curves for gaseous molecules at two different temperatures.
- Compare the variation of distribution of kinetic energy of molecules at different temperatures using the above curves.
- Explain the reasons for speeding up a reaction when the temperature is increased.

Suggestions for Assessments:

- Assess the ability to draw Boltzmann distribution curves for a given gas at given temperatures.
- Assess the ability to draw energy profiles for the given exothermic and endothermic single step reactions.
- Assess the ability to compare the activation energy of forward and backward reaction of a given reversible reaction.

Competency Level 11.3 : **Controls the rate of a reaction by appropriately manipulating the concentration of reactants**

Number of periods : 16

Learning Outcomes :

Student should be able to

- display initial rate, instantaneous rate and average rate of a reaction using suitable graphs.
- explain how the order of the reaction with respect to a given reactant and concentration of that reactant affects the rate of the reaction.
- define the rate law for reactions as, rate $= k\,[A]^x\,[B]^y$.
- define the terms in the rate law.
- write the rate law (equation) for zeroth, first and second order reactions.
- derive the units of the rate constant (coherent SI units and non-coherent SI units) for zeroth, first and second order reactions.
- interpret the overall order of a reaction.
- demonstrate graphically how the rate changes with concentration for a zeroth order, first order and second order reaction.
- define and interprets half-life of a reaction.
- explain that half life of first order reactions does not depend on the initial concentration.
- provide examples for reactions of different orders.
- conduct experiments to illustrate zeroth order, first order and second order reactions.
- determine order of reactions with respect to various reactants by handling appropriately the information obtained from experiments.
- solve problems related to rate law and order of reactions.

Guidance for lesson planning :

- State the ways of expressing the rate of a reaction.
- Define the initial rate, instantaneous rate and average rate of a reaction using suitable examples.
- Describe the effect of concentration on reaction rate introducing the rate law.
- Define the terms rate constant and order of a reaction with respect to a certain reactant.
- Define overall order of a reaction.
- Write the rate law expressions for a different reactions given.
- Derive the units of the rate constant for zeroth order, first order and second order reactions.

- Draw graphs to show the variation of rates with the concentration of reactants for different types of reactions.
- Draw graphs to show the variation of the concentration with the time.
- Define half life($t_{1/2}$) of a reaction.
- Compare the half life of zeroth, first and second order reactions.
- Emphasize that the half life of a first order reaction does not depend on the concentration of a reactant by using suitable graphs.
- Explain how to conduct experiments to determine the order of the reaction between Mg and HCl and the reaction between $Na_2S_2O_3$ and HNO_3 acid.
- Solve problems to study the rate law by using given data for the different reactions.

Relevant practical work :

- Experimental determination of the effect of acid concentration on the rate of the reaction between Mg and acids.
- Experimental determination of the effect of concentration of each reactant on the rate of the reaction rate between $Na_2S_2O_3$ and HNO_3..

Suggestions for Assessments:

- Assess the ability to write expressions of rate law for given reactions.
- Assess ability to determine the order of reactions with respect to given species using given experimental data.
- Assess ability to calculate the half life of a reaction using given data.

Competency Level 11.4 : **Investigates the effect of physical nature and catalysts on reaction rate**

Number of periods : 02

Learning Outcomes :

Student should be able to

- state that when surface area of a solid reactant increases, rate of reaction also increases due to the increase in the number of collisions.
- describe the effect of catalysts in terms of the activation energy for a reaction.

Guidance for lesson planning :

- Explain the effect of physical nature of reactants on reaction rate using the requirements that should be satisfied to bring about chemical reactions.
- Describe the effect of catalysts on reaction rates by using the Boltzmann distribution curves and the concept of activation energy.

Suggestions for Assessments:

- Assess the ability to distinguish between a catalyzed reaction and an unanalyzed reaction by using energy profile diagrams.

Competency Level 11.5 : **Uses reaction mechanisms to describe the rate of chemical reactions**

Number of periods : 11

Learning Outcomes :

Student should be able to

- distinguish elementary reactions from multistep reactions.
- explain the relationship between the mechanism of a reaction and the order of a reaction.
- draw energy profiles.
- write the intermediates and transitions states of the energy diagram.
- explain the molecularity and the order of the elementary and multistep reactions.
- construct energy profiles for reactions to explain the events that follow collisions using basic principles of energetics.
- explain the effect of concentration of iron(III) ions on the reaction rate of the reaction between Fe^{3+} and I^-.
- explain the relationship between the mechanism of a reaction and the order of a reaction.
- determine the rate determining step and reaction mechanisms using energy profiles.

Guidance for lesson planning :

- Introduce multistep reactions giving suitable examples.
- Distinguish between elementary reactions and multistep reactions using their reaction mechanisms.
- Explain the relationship between the mechanism of a reaction and order of a reaction.
- Draw energy profile diagram for multistep reactions.
- Introduce intermediates and transition states of a given reaction using suitable examples.
- Define the molecularity of a reaction.
- Explain the rate determining step of a multistep reaction.
- Explain the effect of concentration of iron(III) ions on the reaction rate for the reaction between Fe^{3+} and I^- the mechanism of the reaction.

Relevant practical work :

- Experimental determination of the order with respect to $Fe^{3+}$of the reaction between Fe^{3+} and I^-.

Suggestions for Assessments:

- Assess the ability to identify the rate determining step of a reaction when the steps are given.
- Assess the ability to draw energy profile diagram for a given multistep reaction with a catalyst and without a catalyst.

Unit – 12 Equilibrium

Competency 12.0 : **Uses the concept of equilibrium and its principles to determine the macroscopic properties of closed systems in dynamic equilibrium**

Competency level 12.1 : **Quantitatively determines the macroscopic properties of systems with the help of the concept of equilibrium**

No of Periods : **19**

Learning Outcomes :

Student should be able to

- explain the dynamic equilibrium using the reversible reactions in closed systems.
- state that macroscopic properties of a system remains unchanged after reaching the equilibrium.
- use physical and chemical processes such as changes of state, equilibria in solutions, chemical systems, ionic systems, sparingly soluble systems and electrodes as examples to describe the systems in equilibrium.
- state the equilibrium law.
- write the equilibrium constants (K_c, K_p) for the homogeneous and heterogeneous systems given.
- define Q(reaction quotient).
- compare Q and K.
- state that the equilibrium constant of a system remains unchanged with the constant temperature.
- derive the relationship between K_p and K_c.
- explain the equilibrium point.
- describe how concentration, pressure, temperature and catalysts affect the equilibrium point.
- state Le Chatelier Principle.
- predicts the effect of Le Chatelier Principle on equilibrium system, which disturbed by an external effect of concentration, pressure and temperature.
- solve problems based on K_p,K_c and $K_p=K_c(RT)^{\Delta n}$
- examine the effect of concentration on the equilibrium system Fe^{3+}/ SCN^-.
- examine the effect of pressure on the equilibrium system NO_2/N_2O_4.

Guidance for lesson planning :

- Discuss the equilibrium systems using examples in day to day life.
- Introduce the concept, "dynamic equilibrium" by using the above examples.
- Give an idea about the reversibility of equilibrium systems by demonstrating the CrO_4^{-2}/ $Cr_2O_7^{2-}$ system.

- Discuss the characteristic properties of an equilibrium system.
- Discuss the types of dynamic equilibrium systems using suitable examples. (chemical, ionic, phase and electrode equilibrium systems)
- Define the law of equilibrium.
- Introduce the chemical equilibrium systems using suitable examples.
- Allow to write expressions for equilibrium constants (K_p and K_c) for given chemical systems.
- Define Q (reaction quotient)and compare Q and K.
- Derive the relationship between K_p and K_c.
- emphasze that the equilibrium constant remains unchanged with the constant temperature.
- Give instructions to calculate K_p and K_c for chemical equilibrium systems using the given data.
- Introduce equilibrium point.
- Discuss the factors (temperature, concentration / pressure) that can affect an equilibrium system.
- Describe the Le Chatelier principle.
- Describe how the above mentioned factors can affect the equilibrium systems using Le Chatelier principle.
- Allow to solve problems based on K_p, K_c. and K_p, $K_c(RT)^{\Delta n}$

Relevant practical work :

- Experimental study of the characteristics of a dynamic equilibrium system using Fe^{3+}/ SCN^- system.
- Experimental study of the effect of temperature on the equilibrium system of NO_2 and N_2O_4.

Suggestions for Assessments:

- Assess the ability to explain how the equilibrium point is changed by disturbing the system.
- Assess the ability to solve the different types of problems related to K_p and K_c using the given data.

Competency level 12.2 : **Quantifies properties of ionic equilibrium systems related to weak acids, weak bases, acidic salts and basic salts**

No of Periods : 26

Learning Outcomes :

Student should be able to

- describe Arrhenius theory, Bronsted-Lowry theory and Lewis theory giving appropriate examples.
- categorize acids and bases as weak and strong.
- explain conjugate acids and bases with example.
- write expression for K_w considering self- ionization of water.
- give expressions for K_a and K_b.
- derive equations for K_a and K_b and the law of dilution.
- derive the relationship between K_a and K_b of conjugate acid-base pairs.
- solve problems using K_w, K_a and K_b.
- define *pH*.
- clarify the hydrolysis of salts.
- Calculate *pH* of aqueous solutions of acids and bases.
- Calculate *pH* values of salt solutions considering hydrolysis of cations and anions.
- solve problems using titrations.
- state that *p*H indicators are either weak acids or weak bases.
- express that indicators exhibit different colours for their unionized and ionized forms.
- state that *pH* range (colour change interval) of an indicator depends on the value of dissociation constant of the indicator (K_{In}).
- point out that the selection of an indicator depends on its pK_{In} value which corresponds to the equivalence point *pH* of the titration or *pH* range in which the abrupt *pH* change occurs.
- apply theory of indicators to choose the correct indicator for a particular titration.
- calculate the *pH* value of acid/ base reactions at the equivalence point.
- sketch titration curves for different types of acid - base titrations.
- state that near the equivalence point, an abrupt *pH* change occurs for a small volume of the solution added.
- discuss qualitatively the main features of the titration curve for the titration between Na_2CO_3 and HCl.

- determine experimentally, the acidic/basic/neutral nature of aqueous solutions of salts by testing *pH*.
- titrate between Na_2CO_3 and HCl using phenolphthalein and methyl orange.

Guidance for lesson planning :

- Inquire into prior knowledge about acids and bases.
- Introduce the theories on acids and bases (Arrhenius theory, Bronsted-Lowery theory and Lewis theory)
- Explain the conjugate acids and bases using suitable example.
- Derive an expression for K_w, considering the self- ionization of water.
- Derive an expressions for K_a and K_b considering dissociation of weak acids and weak bases in aqueous medium.
- Derive the relationship between K_a and $K_b$for conjugate acid – base pairs.
- Define the term *pH.*
- Allow to calculate *pH* values for given solutions of acids and bases.
- Allow to write reactions for hydrolysis of cations and anions.
- Allow to calculate the *pH* values for salt solutions.
- Investigate the prior knowledge about indicators.
- Discuss the theory of indicators (colour changes, pH ranges, pK_{In}).
- Emphasize that acid – base indicators are either weak acids or weak bases.
- Explain that indicators exhibit different colours for their unionized and ionized forms.
- State that *pH* range of an indicator depends on the value of dissociation constant, $K_{In.}$
- Explain how to select a correct indicator for a particular acid – base titration.
- Allow to calculate the *pH* value at the end point in acid/ base reactions.
- Illustrate the titration curves for different types of acid - base titrations.
- Explain the abrupt *pH* change near the equivalence point of a titration.
- Discuss the theory of titration between Na_2CO_3 and HCl.
- Allow to solve problems related to titrations.

Relevant practical work :

- Experimental determination of the acidic/ basic/ neutral nature of aqueous solutions of salts by testing *pH.*

- Titration between Na_2CO_3 and HCl using phenolphthalein and methyl orange as indicators.

Suggestions for Assessments:

- Evaluate the ability to calculate *pH* values of different types of solutions. Examples -
  - 0.1 $moldm^{-3}$ HCl solution
  - 0.1 $moldm^{-3}$ NaOH solution
  - 0.1 $moldm^{-3}$ CH_3COOH solution (K_a = 1.8 x 10^{-5} $moldm^{-3}$)
  - 0.1 $moldm^{-3}$ NH_4OH solution (K_b = 1.8 x 10^{-5} $moldm^{-3}$)
  - A mixture of 250 cm^3 of 0.1 $moldm^{-3}$ HCl solution and 250 cm^3 of 0.1 $moldm^{-3}$ CH_3COOH solution.
  - A mixture of 500 cm^3 of 0.1 $moldm^{-3}$ HCl solution and

    250 cm^3 of 0.1 $moldm^{-3}$ NaOH solution.
- Assess the ability to select the suitable indicator from the given indicators for given titrations.

Unit – 12 Equilibrium

Competency level 12.3 : Prepares buffer solutions according to the requirements

No of Periods : 12

Learning Outcomes :

Student should be able to

- define a buffer solution.
- investigate buffer solutions qualitatively and quantitatively.
- derive Henderson equation for monobasic and monoacid buffer systems.
- use Henderson equation for simple calculations.
- explain *pH* of a buffer system qualitatively and quantitatively.

Guidance for lesson planning :

- Conduct a discussion to make students aware about buffer systems existing in nature.
- Define a buffer solution.
- Explain how to prepare a buffer solution using acids and bases.
- Introduce the types of buffer solutions.
- Derive Henderson equation for monobasic and monoacid buffer systems.
- Allow to calculate *pH* values of buffer systems using Henderson equation.

Suggestions for Assessments:

- Assess the ability to calculate *pH* value for given mixtures using Henderson equation.

  e.g: Calculate the *pH* of the following mixture.

  $100 cm^3$ of $0.1 moldm^{-3}$ CH_3COOH solution and $50 cm^3$ of $0.1 moldm^{-3}$ NaOH solution.

Competency level 12.4 : **Quantifies properties of equilibrium systems related to sparingly soluble ionic compounds (Heterogeneous ionic equilibrium)**

No of Periods : 12

Learning Outcomes :

Student should be able to

- state that some ionic compounds are very soluble in water but some are less soluble.
- .apply the principle of equilibrium for a sparingly soluble electrolyte and defineK_{sp}.
- states requirements for precipitation of ionic compound from the aqueous solution.
- solve problems related to K_{sp} of a sparingly soluble electrolyte.
- apply common ion effect .
- identify the cations by precipitation and subsequent solubility of the precipitate in different reagents.
- explain the solubility of the precipitate based on the solubility product principle.
- divide the cations listed into five groups, based on the solubility.products of the ionic compounds of the cations under different conditions.
- determine theK_{sp} of $Ca(OH)_2$experimentally.

Guidance for lesson planning :

- Allow to divide given ionic compoundsin to two groups as soluble and insoluble in water.
- Emphasize that ionc compounds which are apparently insoluble are really sparingly soluble.
- Write the equation for the equilibrium existing in a saturated solution of a sparingly soluble ionic compound.
- Derive an expression for K_{sp} for the above equilibrium.
- Discuss the requirement for precipitation of a compound.
- Allow to write expressions for K_{sp} for sparingly soluble ionic compounds given.
- Explain the common ion effect using suitable examples and calculations.
- Allow to solve appropriate problems based on the common ion effect.
- Explain the principle of group analysis.
- Explain how to separate a mixture of cations into groups using the above principle.

Relevant practical work :

- Experimental determination of the solubility product of $Ca(OH)_2$.

Suggestions for Assessments:

- Assessthe ability to solve problems using K_{sp} and common ion effect by giving appropriate problems.
- Assess the ability to identify cationsin a given cationic mixture using group analysis.

Competency level 12.5 : **Investigates how liquid-vapuor equilibrium varies in single component systems.(phase equilibrium)**

No of Periods : **04**

Learning Outcomes :

Student should be able to

- describe a phase giving suitable examples.
- identify pure liquid systems.
- explain liquid-vapour equilibrium on the basis of molecular motion.
- define the saturated vapour pressure.
- define the boiling temperature.
- explain the variation of vapour pressure of liquids with temperature.
- identify the relationship between the vapour pressure and the boiling point.
- define the critical temperature.
- name the triple point of water using the phase diagram.

Guidance for lesson planning :

- Explain what is a phase using suitable examples.
- Allow to identify the number of phases in a given equilibrium system.
- Explain the liquid – vapour equilibrium system on the basis of molecular motion.
- Define the saturated vapor pressure of a pure liquid.
- Define the boiling point of a pure liquid.
- Explain the variation of vapour pressure of liquids with temperature using graphs.
- Describe the relationship between the vapour pressure and the boiling point.
- Define the critical temperature.
- Name the triple point of water using the phase diagram.

Suggestions for Assessments:

- Assess the ability to draw relevant graphs (vapour pressure vs temperature) using the given data of boiling points of different liquids.

Competency level 12.6 : **Investigates the variation of liquid – vapour equilibrium in binary liquid systems**

No of Periods : **12**

Learning Outcomes :

Student should be able to

- classify the liquid - liquid systems as totally miscible, partially miscible and totally immiscible by giving examples.
- apply the principles of equilibrium and chemical kinetics to a binary liquid system to derive Raoult law.
- define an ideal solution.
- explain how and why non-ideal solutions deviate from Raoult law, using graphs between composition and vapour pressure.
- applyRaoult law to find liquid and vapour phase compositions at equilibrium.
- describe ideal and non-ideal behaviours of binary systems.
- state that simple distillation can be used to separate non - volatile components in a volatile liquid.
- give examples for simple distillation and fractional distillation.
- state that fractional distillation can be used to separate volatile components in a volatile liquid mixture.

Guidance for lesson planning :

- Give some examples for totally miscible liquid- liquid systems.
- Derive Raoult law applying the principles of equilibrium and kinetics for a binary liquid system.
- Define an ideal solution using suitable examples.
- Explain the positive and negative derivations of binary solutions from ideal behavior using graphs between the composition and vapour pressure.
- Allow to calculate the composition of liquid phase and vapour phase using Raoult law.
- Explain the principle of simple distillation and fractional distillation.
- Draw temperature – composition phase diagrams to explain the fractional distillation.

Suggestions for Assessments:

- Assess the ability to draw correct vapour pressure- composition diagrams for the given binary solutions.

Example:

1. hexane and heptane
2. ethanol and benzene
3. chloroform and acetone

Competency level 12.7 : **Investigates the distribution of a substance between two immiscible liquid systems**

No of Periods : **09**

Learning Outcomes :

Student should be able to

- give examples for totally immiscible liquidseg: CCl_4 and H_2O, $CHCl_3$and H_2O, $C_6H_6$and H_2O
- explain the partition coefficient K_D.
- state the requirements to apply the Nernst distribution law.
- solve problems using K_D.
- determine experimentally, the distribution coefficient of ethanoic acid between water and 2- butanol.

Guidance for lesson planning :

- Give examples for immiscible liquids.
- Explain the partition coefficient K_D of a substance distributed between two immiscible solvents using suitable examples.
- Allow to solve problems related to K_D using given data.
- Give the requirements to apply the Nernst distribution law.

Relevant practicalwork :

- Experimental determination of distribution coefficient of ethanoic acid between water and 2-butanol.

Suggestions for Assessments:

- Assess the ability to solve problems based on K_D using given data.

Unit 13 – Electro chemistry

Competency13.0 : Investigates the importance of electrochemical systems

Competency level 13.1 : Uses conductivity to understand the nature of solutes and their concentration in an aqueous solution

No of Periods : 04

Learning Outcomes :

Student should be able to

- state the terms strong electrolyte, weak electrolyte and non electrolyte.
- state examples for strong electrolytes, weak electrolytes and non electrolytes in an aqueous medium.
- compare electrical conductors and ionic conductors in terms of current carrying entities.
- express that the electrode reactions at both electrodes are necessary to pass a current through an electrolyte.
- define the terms resistance and resistivity.
- define the terms conductance and conductivity.
- state the factors that affect the conductivity of an electrolyte solution.

Guidance for lesson planning :

- Introduce the terms strong, weak and non – electrolytes giving examples.
- Explain the current carrying mechanism using mobile electrons and ions when conducting electricity.
- Show that the chemical reactions should occur at both electrodes to pass a current through an electrolyte.
- Define the terms resistance, resistivity, conductance and conductivity.
- Discuss the factors that can affect the conductivity of an electrolytic solution (concentration, temperature, nature of the electrolyte etc).
- Use the given data to compare the conductivity of different water samples.

Suggestions for Assessments:

- Assess the ability to classify the given chemicals as strong electrolytes, weak electrolytes and non electrolytes.
- Evaluate the ability to categorize them into ionic and electronic conductors.

Competency level 13.2 : **Investigates electrodes in equilibrium and electrode reactions related to them**

No of Periods : **06**

Learning Outcomes :

Student should be able to

- sketch metal- metal ions electrodes .
- write the reversible electrode reactions for common metal-metal ion electrodes by giving examples.
- describe the existence of a potential difference between an electrode and its solution at the electrode/electrolyte interface.
- illustrate different types of electrodes (gas electrodes, metal- metal ion electrodes, metal-insoluble salt, redox electrodes).
- write the reversible electrode reactions for different types of electrodes.
- define the standard electrode.
- denote electrodes using the standard notation.

Guidance for lesson planning :

- Explain how to construct a metal- metal ion electrode.
- Sketch metal- metal ion electrodes using suitable examples.
- Define the standard metal-metal ion electrode.
- Describe how a potential difference is developed between the metal and the electrolytic solution and inability of measuring that potential directly.
- Explain why the electrode potential difference cannot be measured directly.
- Define the standard electrode indicating the standard conditions.
- Introduce the different types of electrodes.

  Metal insoluble salt electrodes

  Gas electrodes (O_2, H_2, Cl_2)

  Redox electrodes
- Explain how to prepare the above electrodes using suitable examples.
- Explain how to write the half electrode reaction for the above electrodes.
- Define the standard notation of an electrodes.

Suggestions for Assessments:

- Assess the ability to sketch the electrodes , half electrode reactions and indicate the standard notation for the different type of electrodes given.

Competency level 13.3 : **Determines the properties of electrochemical cells**

No of Periods : **15**

Learning Outcomes :

Student should be able to

- state the use of liquid junction, salt bridge/separator.
- give examples for a cell without a liquid junction.
- describe the term electrode potential of an electrode.
- introduce the standard hydrogen electrode as a reference electrode.
- define the standard electrode potential of an electrode.
- explain how to measure the standard electrode potential of an electrode.
- state the factors affecting the electrode potential.
- state the silver-silver chloride and calomel electrode as practical reference electrodes.
- give examples for electrochemical cells with diagrammatical representations.
- present the conventional notation of an electrochemical cell with standard rules.
- write the electrode reactions in a simple electrochemical cell.
- define the term electromotive force.
- solve simple problems related to electromotive force.
- describe the factors affecting electromotive force.
- name the cells used in daily life.(Leclanche cell, Lead accumulator)
- draw the diagram of the Daniel cell.
- constructs the electrochemical series using the standard electrode potentials.
- describe relationship between the position of metals in the electrochemical series and their existence, method of extraction and chemical properties.
- determine the relative position of commonly available metals in the electrochemical series experimentally.
- prepare the standard Ag(s), AgCl(s)/Cl^-(aq) electrode in the laboratory.

Guidance for lesson planning :

- Define the term electrode potential of an electrode.
- Define the standard hydrogen electrode.
- Illustrate the standard hydrogen electrode indicating its importance as the reference electrode.
- Define the term standard electrode potential of an electrode E^0.
- Explain how to measure the standard electrode potential of an electrode using the standard hydrogen electrode.

- Discuss the factors that can affect the standard electrode potential.
- Give the structure of silver-silver chloride electrode as the practical reference electrode instead of using standard hydrogen electrode.
- Explain how to construct an electrochemical cell and how to represent it by a diagram.
- Describes the electrochemical cells with and without a liquid junction.
- Write the electrode reactions at anode and cathode in an electrochemical cell.
- Introduce the standard notation of an electrochemical cell by using several examples.
- Introduce the term, standard electromotive force of an electrochemical cell by giving the equation, $E^0cell = E^0(cathode) - E^0(anode)$.
- Discuss the factors that affect the electromotive force.
- Compare E^0cell values of different electrochemical cells.
- Explain how to construct the electrochemical series using different standard electrode potential values of electrodes.
- Describe relationship among the position of metals and non metals in the electrochemical series and their extraction methods.

Relevant practical work :

- Experimental determination of the relative position of commonly available metals in the electrochemical series.
- Preparation of standard Ag(s), AgCl(s)/Cl^-(aq)electrode.

Suggestions for Assessments:

- Assess the knowledge about electrochemical cells by giving the following type of questions. (Give the E^0values of Mg^{2+}(aq) /Mg(s) and Zn^{2+} (aq) /Zn(s) electrodes)

  Example-:

  Consider the electrochemical cell prepared by the standard zinc electrodeand students magnesium electrode.

  1. Write the standard notation of the above cell.
  2. Write the half cell reactions occurting at the cathode and the anode.
  3. Write the overall cell reaction.
  4. What is the negative terminal of this cell?
  5. What is the positive terminal of this cell?
  6. Calculate the E^0 *cell*.

Competency level 13.4 : **Identifies the requirements to be fulfilled in the process of electrolysis and carries out related calculations using Faraday constant**

No of Periods : **08**

Learning Outcomes :

Student should be able to

- define electrolysis.
- describe principles of electrolysis.
- predict the products of simple electrolytic systems.
- solve simple problems based on the Faraday constant.

Guidance for lesson planning :

- Define the term electrolysis.
- Discuss the principles of electrolysis.
- Explain the different types of electrolytic systems using inert and active electrodes.

  Electrolysis of molten NaCl.(NaCl(l))

  Electrolysis of aqueous solutions (NaCl(aq), $CuSO_4$ (aq) solutions using Cu electrodes).
- Discuss how to predict products obtained during electrolysis.
- Explain how to use Faraday constant to solve problems related to electrolysis.

Suggestions for Assessments:

- Assess the ability to write relevant products obtained by the given electrolytic processes.
- Evaluate the ability to calculate the mass of elements discharged during the electrolysis by using Faraday constant.

Unit 14 : IndustrialChemistryand Environmental Pollution

Competency 14.0 : Investigates the selected chemical industries to understand the applications of principles and identify industrial pollutants

Competency level 14.1 : **Investigates the production and uses of elements and compounds of s block**

No of Periods : 11

Learning Outcomes :

Student should be able to

- list out the factors to be considered for designing a chemical industry.
- describe factors to be considered to select natural raw materials for an industry.
- describe physico-chemical principles involved in the production of Mg, NaOH, $Na_2CO_3$and their uses.
- prepare a soap sample in the laboratory and describe how to improve the quality of the product.

Guidance for lesson planning :

- Conduct a discussion to find out whether chemical industries are established in the surrounding area.
- Ask the students to name the chemical industries in Sri Lanka at present.
- Discuss the factors to be considered for designing a chemical industry.
- Describe factors to be considered to select a natural raw materials for an industry.
- Explain the physico – chemical principles and the methods in extracting magnesium metal from the bittern solution obtained in the production of common salt NaCl using sea water as a raw material (Dow process).
- List the uses of magnesium.
- Explain the physico- chemical principles involved and the methods of producing NaOH by the membrane cell method.
- State the uses of NaOH and by - products of the production of NaOH.
- Explain the physic - chemical principles in volved and the method of producing Na_2CO_3 by the Solvay process.
- State the uses of Na_2CO_3.
- Express the advantages of reuse of the by- products in manufacturing Na_2CO_3.
- Explain the physico chemical principles involved and the method of production of soap.
- Present the uses of glycerol formed as a by - product of soap industry.

Relevant practicalwork :

- Preparation of a soap sample in the laboratory.

Suggestions for Assessments:

- Assess through a group activity the ability to construct a flow chart connecting the industries studied.

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Competency level 14.2 : Investigates the production and uses of the compounds and elements of p block elements

No of Periods : 08

Learning Outcomes :

Student should be able to

- describe the physico- chemical principles involved in the production of ammonia, nirtic acid and sulphuric acid and identify their uses.

Guidance for lesson planning :

- Discuss the physico-chemical principles involved and the method of production of ammonia by Haber process.
- State the uses of ammonia.
- Discuss the physico-chemical principles involved and the method of production ofHNO_3 by the Ostwald method.
- State the uses of HNO_3.
- Discuss the physico-chemical principles involved and the method of production of H_2SO_4 by the contact process.
- State the uses of H_2SO_4.

Suggestions for Assessments:

- Assess the ability to write balanced chemical equations to indicate how to synthesise a sample of NH_4NO_3 by using H_2, N_2 and O_2 as raw materials.

Competency level 14.3 : Investigates production and uses of d-block elements and their compounds

No of Periods : 04

Learning Outcomes :

Student should be able to

- describe production and physico-chemical principlesinvolved used in the production of titanium dioxide.
- describe the uses of TiO_2.
- describe physico-chemical principles involved in the extraction of iron by the blast furnaces method.

Guidance for lesson planning :

- Ask about the places of occurrence and sources of Ti in Sri Lanka.
- Explain the main steps of producing TiO_2 from rutile and indicate the uses of TiO_2.
- Explain the main steps of extraction of iron.
- State the uses of iron.

Suggestions for Assessments:

- Assess the ability to write the uses of Ti , TiO_2 and Fe in day to day life.

Competency level 14.4 : **Investigates the chemistry of polymeric substances**

No of Periods : **08**

Learning Outcomes :

Student should be able to

- introduce polymers, monomers and repeating units.
- classify polymers as natural and synthetic with examples.
- classify polymers according to the type of the polymerization reactions as addition and condensation.
- identify the structures (monomer, polymer and repeating unit), properties and uses of given polymers.
- describe the types of plastic additives and their effects on the environment.
- describe structure, properties and uses of natural rubber.
- describe the process of vulcanization of rubber.
- explain the process of coagulation of rubber and prevention of coagulation.

Guidance for lesson planning :

- Question the prior knowledge about polymers used in day to day life.
- Allow to categorize the above polymers according to different criteria.
- Introduce polymers by explaining the monomer and repeating unit.
- Classify all synthetic polymers as addition polymers and condensation polymers according to the methods of formation.
- Introduce the addition polymers (polythene, teflon, polystyrene, and PVC by using relevant reactions.
- Introduce nylon and polyester as condensation polymers by using relevant reactions.
- Give the structure of bake lite as an example for a 3D polymer.
- Indicate the uses of the above polymers.
- Discuss the types of plastic additives (fillers, plastiinges colourings, fire resistors) used in polymerization to develop their properties.
- Discuss environmental impact of using polymers.
- Introduce natural rubber as a natural polymer.
- Explain the elasticity of rubber referring to it's structure.
- Explain about vulcanization as a method of improving mechanical properties of rubber.

- Give the composition of rubber latex and the methods of coagulation and how to prevent coagulation.
- Emphasize that solid rubber can be obtained by coagulating rubber latex.

Suggestions for Assessments:

- Assess the ability to identify the monomers, repeating units and polymers like polythene, teflon and PVC.
- Assess the ability to write the uses of polymers.

Competency level 14.5 : Investigates some chemical industries based on plant materials

No of Periods : 12

Learning Outcomes :

Student should be able to

- describe plants as a renewable raw material.
- write the equations for the reactions of formation of ethanol and vinegar from glucose.
- describe the production of biodiesel.
- describe essential oils as complex mixtures of volatile constituents of plants.
- explain the principles of steam distillation used to extract essential oils.
- state the uses of ethanol, vinegar, essential oils and biodiesel .
- extract cinnamon oil from cinnamon leaves in the laboratory.
- prepare a sample of biodiesel in the laboratory.
- calculate the percentage of acetic acid in a vinegar sample in the laboratory.

Guidance for lesson planning :

- Check the prior knowledge about the chemicals that can be extracted from plants.
- Emphasize that the plants are renewable raw materials.
- Ask about the plant materials that can be used to prepare ethanol and vinegar.
- Explain the steps of preparing ethanol and vinegar through relevant chemical reactions.
- Explain the steps of preparing biodiesel from plants.
- Discuss the advantages of biodiesel as a solution for the impending energy crisis in the future.
- Explain the method of steam distillation to extract cinnamon oil from cinnamon leaves.
- Emphasize that the essential oils can be considered a mixture of different volatile components.
- Explain the uses of essential oils.

Relevant practical work:

- Extraction of cinnamon oil from cinnamon leaves by steam distillation.
- Preparation of a sample of biodiesel.
- Determination of the percentage of acetic acid in a sample of vinegar.

Suggestions for Assessments:

- Assess the ability of students to calculate the concentration of CH_3COOH in a vinegar sample by giving following types of problems.

  Example-:
  25.00 cm^3 of a certain vinegar sample is measured and diluted up to 250.0 cm^3 by distilled water.When 25.00 cm^3 of this solutions was titrated with 0.1 mol dm^{-3} NaOH, the burette reading was 16.0 $cm^{3.}$

  1. Calculate the concentration of CH_3COOH in the vinegar sample.
  2. Calculate the acid percentage of in this sample.
  3. Indicate one suitable indicator for this titration.

Competency level 14.6 **: Chemistry of air pollution by industrial emissions**.

No of Periods **: 07**

Learning Outcomes **:**

Student should be able to

- name air quality parameters such as CO_x, NO_x, SO_x, C_xH_y, and particulate matter in air.
- explain the chemistry of acid rains and their effect on the environment.
- explain the chemistry of photochemical smog and its effect on the environment.
- explain the ozone layer depletion and its effect on the environment.
- explain the chemistry of greenhouse effect, global warming and their effect on the environment.
- describe precautionary measures that can minimize air pollution.

Guidance for lesson planning :

- Name of quality parameters such as CO_x,NO_x,SO_x,C_x Hy and particulate matter in air.
- Question the prior knowledge about acid rain.
- Name the gaseous pollutants (SO_x, NO_x) that contribute to acid rain.
- Explain how acid rain is formed by the above pollutants by considering relevant chemical reactions.
- Discuss the effect of acid rain on the environment (indicate necessary reactions whenever required.)
- Explain photochemical smog by considering the factors that can affect the photochemical smog and the way of identifying it.
- write relevant reactions occurring during the above process.
- Discuss the adverse effects of photochemical smogs on the environment, substances and human health.
- Explain the chemistry associated with the ozone layer depletion.
- Discuss the relevant gases that contribute to ozone layer depletion.
- Indicate the environmental impact caused by ozone layer depletion.
- Question the prior knowledge about the greenhouse effect.
- Show how global warming occurs when permissible levels of greenhouse gases are exceded.
- Explain the environmental effects caused by global warming.
- Indicate the precautions that can be followed by industries to minimize air pollution.

Suggestions for Assessments:

- Assess the ability to conduct a presentation about acid rain, greenhouse effect, ozone layer depletion and photochemical smog by dividing students into four groups.
  (one group can select one topic)

Competency level 14.7 : Chemistry of water pollution by industrial discharges

No of Periods : 07

Learning Outcomes :

Student should be able to

- name water quality parameters such as *pH*, temperature, conductivity, turbidity, hardness, dissolved oxygen (DO) and chemical oxygen demand (COD) of water.
- record physical parameters such as *pH*, temperature, conductivity, turbidity and hardness of water for a given polluted water sample.
- describe eutrophication and its consequences caused by $\mathrm{NO_3^-}$ and $\mathrm{PO_4^{3-}}$.
- describe the consequences of dissolved organic pollutants.
- explain the common heavy metals causing water pollution and their effect on the environment.
- explain how to identify water pollution using chemical parameters such as DO and COD.
- explain water pollution using physical parameters such as acidity/basicity, thermal pollution, turbidity and hardness of water.
- describe the precautional measures that can be taken to minimize pollution by industrial discharge.
- determine the dissolved oxygen level in (fresh) wate rexperimentally.

Guidance for lesson planning :

- Collect details from students by asking questions about why water bodies (such as ponds, tanks, rivers) are sometimes covered with mosses.
- Introduce *pH* value, turbidity, hardness and temperature as parameters that can be used to check the water quality.
- Introduce the type of ions that can causeeutrophication.
- Indicate how the above ions are added to the water bodies.
- Discuss the problems created by eutrophication.
- Discuss water soluble organic compounds that can be contained in waste water formed by industrial processes.
- Explain the effects of the above processes on the environment and the water quality.
- Inquire into the prior knowledge about heavy metalions that can get mixed with waste water by the industries.
- Discuss the adverse effects brought about by heavy metalions on the environment and on human health.

- Explain how to identify water pollution using the dissolved oxygen (DO) and chemical oxygen demand (COD).
- Discuss the precautions that can be taken to minimize water pollution.

Relevant practical work :

- Practical determination of dissolved oxygen in a water sample using the Winkler method.

Suggestions for Assessments:

- Assess the ability of groups to present the environmental effects of the following industries and the ways of minimizing those effects.
- Production of NH_3byHarber process
- Production of H_2SO_4 by contact process
- Production of NaOH by membrane cell method
- Production of HNO_3 by Oswald process
- Production of $Na_2CO_3$by Solvay process