

UNIT I

Chapter 1 : Water Technology and Green Chemistry

1-1 to 1-63

Impurities in water, hard water, hardness of water, its types, units of hardness and hardness calculation. Chemical analysis of water by determination of hardness by EDTA method. Alkalinity of water and its determination. Numericals on EDTA method and alkalinity. Disadvantages of hard water in boilers. Water softening techniques : Permutit and Ion exchange method. Water purification by reverse osmosis and electro-dialysis. Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD).

Introduction of Green Chemistry : Definition, goals, principles and green synthesis of Polycarbonate.

1.1	Introduction.....	1-2
1.2	Sources of Water.....	1-2
1.3	Impurities in Water.....	1-3
1.3.1	Types of Impurities in Water.....	1-3
1.4	Hardness of Water.....	1-4
1.5	Types of Hardness.....	1-4
1.5.1	Temporary or Carbonate or Alkaline Hardness.....	1-4
1.5.2	Permanent or Non-carbonate or Non-alkaline Hardness.....	1-5
1.6	Measurement of Hardness.....	1-6
1.6.1	Calculation of Equivalents of CaCO ₃	1-6
1.7	Units of Hardness.....	1-7
1.8	Determination of Hardness of Water.....	1-8
1.8.1	Determination of Hardness by EDTA Method.....	1-8
1.8.2	Principle of EDTA Method.....	1-9
1.8.3	Procedure for EDTA Titration.....	1-9
1.8.4	Problems based on Calculation of Hardness by EDTA Method.....	1-10
1.9	Alkalinity.....	1-13
1.9.1	Determination of Alkalinity.....	1-13
1.9.2	Procedure.....	1-14
1.9.3	Problem based on Alkalinity.....	1-15
1.10	Disadvantages of Hard Water.....	1-18
1.10.1	Bad Effect of Hard Water on Boiler.....	1-19
1.10.1(A)	Priming and Foaming.....	1-20
1.10.1(B)	Boiler Corrosion.....	1-21
1.10.1(C)	Caustic Embrittlement.....	1-22



1.10.1(D) Sludge and Scale Formation	1-23
1.11 Treatment of Water	1-26
1.11.1 Softening of Water	1-26
1.11.2 Zeolite or Permutit Process	1-26
1.11.3 Ion Exchange Process / Demineralization/ Deionization Process.....	1-29
1.11.4 Comparison between Ion-Exchange Process and Zeolite Process	1-32
1.11.5 Problems based on Zeolite Process.....	1-33
1.12 Purification of Water.....	1-40
1.12.1 Reverse Osmosis (RO).....	1-40
1.12.2 Electrodialysis (ED).....	1-42
1.13 Wastewater - Types, Characteristics and Regulation.....	1-44
1.13.1 Dissolved Oxygen (DO)	1-44
1.13.2 Biochemical Oxygen Demand (BOD)	1-44
1.13.3 Chemical Oxygen Demand (COD).....	1-46
1.14 Solved Problems	1-47
1.14.1 Problems based on Carbonates and Non Carbonates Hardness (Total, Permanent, Temporary Hardness).....	1-47
1.15 Introduction of Green Chemistry.....	1-52
1.15.1 Goals of Green Chemistry	1-52
1.15.2 Principles of Green Chemistry.....	1-52
1.16 Synthesis of Polycarbonate	1-56

UNIT II**Chapter 2 : Instrumental Analysis and Battery Technology****2-1 to 2-26**

- a) **Electrochemistry : Fundamentals of an electrochemical cell, EMF of cell, reference and indicator electrodes and Nernst Equation.**
- b) **Basic principles, instrumentation and applications of :**
- i) **Conductometry : Introduction, Kohlrausch's law, measurement of conductance and conductometric titrations of strong acid versus strong base, strong acid versus weak base and mixture of acids vs Strong base.**
 - ii) **pH metry : Theory of buffers and preparation, standardization of pH-meter, titration of weak acid versus strong base, simple and differential plots.**

Battery technology : Introduction and types of batteries, construction, working and applications of Lithium ion battery, charging and discharging reactions at respective electrodes.

2.1 Electroanalytical Techniques	2-2
2.2 Electrochemical Cell.....	2-2



2.3	Nernst Equation	2-3
2.4	Types of Electrode.....	2-3
2.4.1	Types of Reference Electrode	2-3
2.4.2	Reference Electrodes	2-4
2.4.3	Gas Electrode (Normal/Standard Hydrogen Electrode- NHE/SHE)	2-4
2.4.4	Saturated Calomel Electrode (SCE).....	2-5
2.5	Indicator Electrode	2-6
2.5.1	Glass Electrode	2-6
2.6	Conductometry	2-7
2.6.1	Conductance by Electrolytes.....	2-7
2.6.2	Factors Affecting Conductivity	2-7
2.6.3	Electrolytic Conductance.....	2-8
2.6.4	Specific Conductance.....	2-8
2.6.5	Equivalent Conductance (λ).....	2-8
2.6.6	Molar Conductance (μ).....	2-9
2.6.7	Cell Constant	2-9
2.6.8	Conductivity Measurement	2-9
2.6.9	Determination of Conductivity of the Solution.....	2-10
2.6.10	Conductometric Titrations	2-12
2.6.10(A)	Acid-base Titrations	2-12
2.6.10(B)	Titration Mixture of Acid vs Strong Base	2-14
2.6.10(C)	Advantages of Conductometric Titrations.....	2-14
2.7	pH Metry.....	2-15
2.7.1	Introduction.....	2-15
2.7.2	pH Meter.....	2-15
2.7.2(A)	Construction and Working of pH Meter	2-16
2.7.2(B)	Standardization of pH Meter	2-17
2.7.3	Acid-base Titration using a pH Meter	2-17
2.7.3(A)	pH metric titration of Weak Acid vs Strong Base.....	2-17
2.7.4	Applications of pH Metry	2-19
2.8	Battery Technology.....	2-19
2.8.1	Types of Batteries	2-20
2.8.2	Fuel Cells	2-20
2.9	Lithium Cells	2-20

UNIT III

Chapter 3 : Spectroscopic Techniques

3-1 to 3-38

Spectroscopic techniques: Ultra Violet and IR spectroscopy

- (a) **UV Spectroscopy** : Nature of electromagnetic radiation and its characteristics. Interaction of matter with UV radiations leading to different electronic transitions. Beer's & Lambert's law, their derivations and applications. Instrumentation of UV -Visible spectrophotometer. Terms used in UV spectroscopy- chromophore, auxochrome, bathochromic shift (red shift), hypsochromic shift (blue shift), hyperchromic and hypochromic effect.
- (b) **IR spectroscopy** : Principle, Condition for IR Spectroscopy, types of vibrations (stretching and bending), Different regions of IR spectrum such as fundamental group region, finger print region and aromatic region. Instrumentation of IR spectrophotometer with applications.

3.1	Spectroscopy	3-2
3.1.1	Terms in Spectroscopy	3-2
3.1.2	Interaction of Electromagnetic Radiation with Matter Absorption and Emission Spectroscopy	3-4
3.2	Ultra Violet Spectroscopy	3-9
3.2.1	Concepts of UV Spectroscopy.....	3-9
3.2.2	Different Electronic Transitions in UV Spectroscopy.....	3-9
3.2.3	Beer's Law and Lambert's Law	3-11
3.2.3(A)	Derivation of the Beer-Lambert Law.....	3-11
3.2.4	Solvents.....	3-13
3.2.5	Terminology	3-13
3.2.6	Single-Beam UV - Spectrophotometer	3-15
3.2.7	Applications of UV-Visible Spectroscopy.....	3-17
3.2.8	Woodward Fieser Rule	3-18
3.3	Infrared Spectroscopy.....	3-21
3.3.1	Concepts of IR	3-21
3.3.2	Principle of IR Spectroscopy	3-21
3.3.3	Condition for IR Spectroscopy.....	3-21
3.3.4	Molecular Vibrations	3-22
3.3.4(A)	Bending Vibrations.....	3-23
3.3.5	Vibrations of Diatomic and Polyatomic Molecules.....	3-23
3.3.6	Features of an Infrared Spectrum.....	3-24
3.3.7	Parts of IR Spectrophotometer.....	3-25
3.3.8	Applications of IR Spectroscopy	3-26

UNIT IV

Chapter 4 : Engineering Materials

4-1 to 4-45

Chemistry of Polymers and Novel Carbon Compounds

- a) **Polymers : Definition, classification of polymers on the basis of thermal behavior, reaction mechanism of free radical and condensation polymerization with suitable examples. Advanced polymeric materials : Structure, properties and applications of liquid crystal polymer - Kevlar, conducting polymers - Polyacetylene, electroluminescent polymer - PPV, biodegradable polymers - PHBV, polymer composite - fibre reinforced polymer and recycling of polymers.**
- b) **Nanomaterials : Definition, types of nanomaterials and properties of nanomaterials. Quantum dots, structure, synthesis, properties and applications of CNTs, Fullerenes and Graphene.**

4.1	Introduction.....	4-2
4.1.1	Polymer.....	4-2
4.1.2	Classification of Polymers	4-3
4.1.3	Characteristic and Properties of Polymers.....	4-3
4.1.4	Polymerization	4-3
4.1.4(A)	Types of Polymerization	4-4
4.1.5	Engineering Thermoplastic	4-5
4.1.5(A)	Thermoplastics or Thermosoftening Plastics.....	4-5
4.1.5(B)	Thermosetting Plastics	4-5
4.2	Free Radical Mechanism.....	4-6
4.3	Speciality Polymers	4-8
4.3.1	Polycarbonate.....	4-9
4.3.2	Biodegradable Polymers	4-10
4.3.2(A)	Types of Biodegradable Polymers	4-11
4.3.3	Conducting Polymer.....	4-13
4.3.3(A)	Intrinsically Conducting Polymers (ICP)	4-13
4.3.3(B)	Doped Conducting Polymers (DCP)	4-17
4.3.3(C)	Extrinsically Conducting Polymers (ECP)	4-17
4.3.3(D)	Co-ordination Conducting Polymers (Inorganic Polymers).....	4-18
4.3.4	Applications of Conducting Polymers	4-18
4.3.5	Electroluminescent Polymer	4-18
4.3.6	Advanced Polymeric Material : Liquid Crystal Polymer	4-20



4.4	Polymer Composites	4-21
4.4.1	Fibre Reinforced Composites.....	4-24
4.5	Recycling of Polymer.....	4-26
4.6	Nanomaterials.....	4-28
4.6.1	Introduction.....	4-28
4.6.2	Properties of Nanomaterials	4-29
4.6.3	Classification of Nanomaterials	4-29
4.6.4	Structure, Properties and Applications of Nanomaterials.....	4-31
4.6.4(A)	Graphene.....	4-31
4.6.4(B)	Carbon Nanotubes (CNT's)	4-32
4.6.4(C)	Fullerene	4-36
4.6.4(D)	Quantum Dots (Semiconductor Nanoparticles)	4-38

UNIT V

Chapter 5 : Fuels and Combustion

5-1 to 5-61

Fuels : Definition, classification of fuels, calorific value and its units. Calorific value (CV), Gross Calorific Value (GCV), Net Calorific Value (NCV). Determination of calorific value - Bomb calorimeter, Boy's calorimeter and numericals.

- i) **Solid fuels : Coal, classification of coal, proximate and ultimate analysis of coal, numericals based on analysis of coal.**
- ii) **Liquid fuels : Origin of petroleum, composition of petroleum, refining of petroleum, Octane number of petrol and Cetane number of diesel. Synthesis reaction, properties, advantages and disadvantages of Power alcohol and Biodiesel.**
- iii) **Gaseous fuels : Hydrogen gas as a future fuel, production by steam reforming of methane and coke, storage and transportation. H₂- O₂ fuel cell.**
- iv) **Combustion : Chemical reactions, calculations on air requirement for combustion.**

5.1	Introduction.....	5-2
5.1.1	Definition	5-2
5.1.2	Classification of Chemical Fuels.....	5-2
5.1.3	Characteristic/Properties of Good Fuels	5-3
5.1.4	Comparison of Solid, Liquid and Gaseous Fuels	5-3
5.2	Calorific Value - GCV and NCV.....	5-4
5.2.1	Units of Calorific Value.....	5-4
5.2.2	High and Low Calorific Values.....	5-5
5.2.3	Dulong Formula	5-5



5.3	Determination of Calorific Value : Principle, Construction and Working of Bomb and Boy's Gas Calorimeter.....	5-6
5.3.1	Determination of C.V. by Bomb Calorimeter	5-6
5.3.2	Boy's Gas Calorimeter	5-7
5.4	Solid Fuels.....	5-9
5.4.1	Coal	5-9
5.4.2	Analysis of Coal	5-10
5.4.2(A)	Proximate Analysis of Coal.....	5-11
5.4.2(B)	Significance/ Importance of Proximate Analysis.....	5-12
5.4.2(C)	Ultimate Analysis of Coal	5-13
5.4.2(D)	Significance of Ultimate Analysis	5-14
5.5	Liquid Fuels.....	5-15
5.5.1	Crude Petroleum Oils.....	5-15
5.5.2	Origin of Petroleum	5-15
5.5.3	Composition of Petroleum	5-16
5.5.4	Mining of Petroleum	5-16
5.5.5	Refining of Petroleum.....	5-17
5.5.6	Power Alcohol.....	5-19
5.5.6(A)	Advantages of Power Alcohol	5-20
5.5.6(B)	Disadvantages of Power Alcohol	5-20
5.5.7	Biodiesel.....	5-20
5.5.7(A)	Method / Steps to obtain Biodiesel - A Green Fuel.....	5-21
5.5.7(B)	Advantages of Biodiesel	5-21
5.6	Gaseous Fuel.....	5-22
5.6.1	Hydrogen Gas as a Future Fuel.....	5-22
5.6.2	Production of H ₂ Gas.....	5-22
5.6.3	Difficulties in Storage and Transportation of H ₂ Gas.....	5-23
5.6.4	Fuel Cells	5-23
5.7	Solved Problems	5-26
5.7.1	Solved Numericals on GCV, NCV Calculations by Dulong Formula	5-26
5.7.2	Solved Numericals on Boy's and Bomb Calorimeter	5-28
5.7.3	Solved Numericals : Combustion of Solid Fuels - Requirement of Weight and Volume of O ₂ and Air	5-32



5.7.4	Solved Numericals : Combustion of Gaseous Fuels - Requirement of Oxygen and Air [Volume and Weight].....	5-44
5.7.5	Solved Numericals on Proximate Analysis.....	5-47
5.7.6	Solved Numericals on Ultimate Analysis	5-51

UNIT VI**Chapter 6 : Corrosion Science****6-1 to 6-34**

Corrosion : Introduction, types of corrosion, mechanism of atmospheric corrosion and wet corrosion. Electrochemical and galvanic series. Factors affecting corrosion : nature of metal and nature of environment.

Corrosion control : Methods of prevention of corrosion - cathodic and anodic protection, metallic coatings and its types - anodic and cathodic coatings. Method to apply metallic coatings - hot dipping, cladding, electroplating and cementation. Non-metallic coating - powder coating.

6.1	Introduction.....	6-2
6.1.1	Corrosion (Definition).....	6-2
6.2	Types of Corrosion.....	6-3
6.2.1	Dry Corrosion.....	6-3
6.2.1(A)	Corrosion due to Oxygen.....	6-3
6.2.1(B)	Corrosion due to Other Gases.....	6-7
6.2.1(C)	Corrosion by Hydrogen	6-8
6.2.2	Wet /Immersed/Electrochemical Corrosion.....	6-8
6.2.2(A)	Electrode Potential	6-9
6.2.3	Mechanism of Wet Corrosion.....	6-9
6.2.4	Types of Electrochemical Corrosion.....	6-11
6.2.5	Comparison between Dry and Wet Corrosion	6-13
6.3	Factors Affecting Rate of Corrosion.....	6-14
6.4	Methods for Corrosion Control	6-16
6.4.1	Material Selection.....	6-16
6.4.2	Proper Designing.....	6-16
6.4.3	Modification of Environment.....	6-17
6.4.4	Use of Inhibitors.....	6-17
6.4.5	Cathodic Protection Method.....	6-18
6.4.5(A)	Comparison between Cathodic and Anodic Protection.....	6-20
6.4.6	Anodic Protection Method	6-20
6.5	Application of Protective Coatings.....	6-21



6.5.1	Metallic Coatings.....	6-22
6.5.1(A)	Comparison between Anodic and Cathodic Coatings.....	6-23
6.6	Methods of Application of Metallic Coatings	6-23
6.6.1	Hot Dipping.....	6-24
6.6.1(A)	Comparison between Galvanizing and Tinning.....	6-26
6.6.2	Metal Cladding.....	6-26
6.6.3	Metal Spraying.....	6-27
6.6.4	Electroplating.....	6-27
6.6.4(A)	Theory of Electroplating	6-28
6.6.4(B)	Process of Electroplating	6-28
6.6.5	Cementation/ Diffusion.....	6-29
6.6.6	Powder Coating.....	6-30

TechKnowledge
Publications