

Contents

Part-I

Introduction to Instrumental Methods of Chemical Analysis

| | | |
|-----------|--|----------|
| 1. | Introduction to Instrumental Methods of Chemical Analysis | 1 |
| 1.1 | Chemical Analysis | 3 |
| 1.2 | Instrumental Methods—Their Classification | 3 |
| 1.3 | Selection of the Instrumental Method | 5 |
| 1.4 | Application of Instrumental Methods/ Techniques | 5 |
| 1.4.1 | Chromatographic Methods | 5 |
| 1.4.2 | Thermal Methods | 5 |
| 1.4.3 | Electrochemical Methods | 5 |
| 1.4.4 | Instrumental Methods for the Determination of the structure of Organic Compounds | 6 |
| 1.4.5 | Instrumental Methods of Analysis of Inorganic Compounds | 8 |
| 1.4.6 | Miscellaneous Instrumental Methods | 9 |

PART II

(Chromatographic Methods)

| | | |
|-----------|--|-----------|
| 2. | Chromatography | 13 |
| 2.1 | Introduction | 13 |
| 2.2 | Principle of Chromatographic Separation | 13 |
| 2.3 | Types of Chromatography | 14 |
| 2.3.1 | Partition Chromatography | 14 |
| 2.3.2 | Adsorption Chromatography | 15 |
| 2.3.3 | Exclusion Chromatography | 15 |
| 2.3.4 | Ion-exchange Chromatography | 15 |
| | Exercises | 16 |
| 3. | Paper chromatography | 17 |
| 3.1 | Circular (or Radical) Paper Chromatography | 17 |
| 3.2 | Ascending Paper Chromatography | 20 |
| 3.3 | Descending Paper Chromatography | 20 |

| | | |
|------------|--|-----------|
| 3.4 | Paper Chromatographic Separations | 21 |
| 3.4.1 | Separation and Identification of Group 1 Cations (Pb ⁺ , Ag ⁺ , Hg ⁺) | 21 |
| 3.4.2 | Separation and Identification of Cations of Group II (Hg ²⁺ , cu ²⁺ , cd ²⁺ and Bi ³⁺) | 22 |
| 3.4.3 | Separation and Identification of cu ²⁺ and cd ²⁺ Using Paper Chromatography | 22 |
| 3.4.4 | Separation and Identification of Amino Acids by Descending Paper Chromatography | 23 |
| 3.4.5 | Separation and Identification of Monosaccharides by Descending paper Chromatography | 24 |
| | Exercises | 25 |
| 4. | Thin layer Chromatography | 27 |
| 4.1 | Principle of TLC Separation | 27 |
| 4.2 | Preparation of TLC Plates | 27 |
| 4.3 | Procedure for TLC | 29 |
| 4.4 | Preparative TLC | 31 |
| 4.5 | Two-dimensional TLC | 32 |
| 4.6 | High-performance Thin-Layer Chromatography (HPTLC) | 33 |
| 4.7 | Reversed Phase Partition Thin Layer Chromatography | 34 |
| 4.8 | Thin Layer Chromatographic Separations | 34 |
| 4.8.1 | Separation and Identification of Amino Acids by TLC | 34 |
| 4.8.2 | Separation and Identification of Carbohydrates by TLC | 35 |
| 4.8.3 | Separation and Identification of Ketones | 35 |
| | Exercises | 36 |
| 5. | Column chromatography | 37 |
| 5.1 | Principle of Column Chromatography | 38 |
| 5.2 | Procedure of Column Chromatography | 38 |
| 5.3 | High Performance Column Chromatography | 40 |
| 5.4 | Dry Column Chromatography | 41 |
| 5.5 | Chiral Chromatography | 42 |
| 5.6 | Columns Chromatographic Separations | 43 |
| 5.6.1 | Separation and Identification of a Mixture of o-nitroaniline and p-nitroaniline by Column Chromatography | 43 |

| | | |
|-----------|--|-----------|
| 5.6.2 | Separation and Identification of a Mixture of <i>cis</i> - and <i>trans</i> -Azobenzene by Column Chromatography | 43 |
| 5.6.3 | Purification of Anthracene by Column Chromatography | 44 |
| | Exercises | 44 |
| 6. | Gas chromatography | 45 |
| 6.1 | Introduction | 45 |
| 6.2 | Principle of Gas Chromatography | 45 |
| 6.3 | The Chromatographic Instrument | 47 |
| 6.3.1 | Carrier Gas | 47 |
| 6.3.2 | Sample Injection System | 47 |
| 6.3.3 | The Column | 48 |
| 6.3.4 | The Detector | 50 |
| 6.3.5 | Temperature Programming | 50 |
| 6.4 | Preparative Gas Chromatography | 50 |
| 6.5 | Applications of Gas Chromatography | 51 |
| 6.6 | Gas Chromatographic Separations | 53 |
| 6.6.1 | Estimation of Sucrose | 53 |
| 6.6.2 | Estimation of Aluminium in Water | 54 |
| | Exercises | 54 |
| 7. | High performance liquid chromatography (HPLC) | 55 |
| 7.1 | Introduction | 55 |
| 7.2 | Principle of HPLC | 55 |
| 7.3 | HPLC Instruments | 56 |
| 7.3.1 | Mobile Phase | 56 |
| 7.3.2 | Sample Injection Systems | 56 |
| 7.3.3 | Column | 56 |
| 7.3.4 | Detector | 57 |
| | Exercises | 57 |
| 8. | Gel Chromatography | 59 |
| 8.1 | Introduction | 59 |
| 8.2 | Principle of Gel Chromatography | 59 |
| 8.3 | Types of Gels | 59 |
| 8.4 | Applications of Gel Chromatography | 61 |
| | Exercises | 61 |

| | |
|---|-----------|
| 9. Ion exchange Chromatography | 63 |
| 9.1 Introduction | 63 |
| 9.2 Different Types of Resins | 64 |
| 9.2.1 Anion Exchange Resins | 64 |
| 9.2.2 Cation Exchange Resins | 65 |
| 9.3 Principle of Ion Chromatography | 65 |
| 9.4 Procedure for Ion Chromatography | 66 |
| 9.5 Applications of Ion Chromatography | 67 |
| 9.5.1 Determination of Anions | 67 |
| 9.5.2 Separation of Li^+ , Na^+ and K^+ Ions | 68 |
| 9.5.3 Removal of Phosphate (interfering radical) | 68 |
| 9.5.4 Softening of Hard Water | 68 |
| 9.5.5 Demineralised Water | 69 |
| 9.5.6 Separation of Amino Acids | 70 |
| Exercises | 71 |
| 10. Electro chromatography | 73 |
| 10.1 Introduction | 73 |
| 10.2 Paper Electrophoresis | 73 |
| 10.3 Gel Electrophoresis | 74 |
| 10.4 Capillary Electrophoresis (CE) | 75 |
| Exercises | 77 |
| PART III | |
| (Thermal Methods of Chemical Analysis) | |
| 11. Thermogravimetric analysis | 81 |
| 11.1 Introduction | 81 |
| 11.2 Thermogravimetric Analysis | 82 |
| 11.3 Thermogravimetric Analyser | 82 |
| 11.3.1 Measurement of Weight | 82 |
| 11.3.2 Heating Arrangement and Temperature Measurement | 83 |
| 11.3.3 Sample Holders | 83 |
| 11.3.4 Atmospheric Control | 83 |
| 11.3.5 Recorders | 83 |
| 11.4 Thermogravimetric Curve (TG curve) | 84 |
| 11.4.1 Factors Affecting Thermogravimetric Curves | 85 |
| 11.5 Applications of TGA | 86 |
| 11.5.1 Determination of Thermal Stability of Salts | 86 |
| 11.5.2 Analysis of Mixtures | 87 |
| 11.5.3 Determination of Curie Temperature | 87 |

| | | |
|------------|--|------------|
| 11.5.4 | Organic Compounds | 88 |
| 11.6.7 | Exercises | 89 |
| 12. | Differential Thermal Analysis | 91 |
| 12.1 | Introduction | 91 |
| 12.2 | Differential Thermal Analyser | 92 |
| 12.3 | Factors Affecting DTA | 93 |
| 12.4 | Applications of DTA | 94 |
| 12.4.1 | Heat of Reaction | 94 |
| 12.4.2 | Specific Heat | 94 |
| 12.4.3 | Identification of Substances | 95 |
| 12.4.4 | Identification of the Products of a Reaction | 95 |
| 12.4.5 | Purity of the Compound | 95 |
| 12.4.6 | Quantitative Analysis | 95 |
| 12.5 | Miscellaneous Applications | 95 |
| | Exercises | 96 |
| 13. | Thermometric Titrations | 97 |
| 13.1 | Introduction | 97 |
| 13.2 | Thermometric Titration Apparatus | 98 |
| 13.3 | Titrimetric Procedure | 99 |
| 13.4 | Applications | 99 |
| 13.4.1 | Neutralisation Titrations | 99 |
| 13.4.2 | Precipitation Titrations | 100 |
| 13.4.3 | Complexation Titrations | 100 |
| 13.4.4 | Redox Titrations | 101 |
| | Exercises | 101 |
| 14. | Miscellaneous thermal methods | 103 |
| 14.1 | Derivative Thermogravimetric Analysis (DTA) | 103 |
| 14.2 | Thermobarography | 103 |
| 14.3 | Differential Scanning Calorimetry (DSC) | 103 |
| 14.4 | Thermomechanical Analysis (TMA) | 104 |
| 14.5 | Electric Thermal Analysis (ETA) | 105 |
| | Exercises | 105 |
| | PART-IV | |
| | (Electrochemical Method) | |
| 15. | Coulometric method of analysis | 109 |
| 15.1 | Introduction | 109 |
| 15.2 | Coulometer | 110 |

| | | |
|------------|---|------------|
| 15.3 | Coulometric Analysis | 111 |
| 15.3.1 | Constant Current Coulometric Analysis | 111 |
| 15.3.2 | Controlled Potential Coulometric Analysis | 112 |
| 15.4 | Coulometric Titrations | 112 |
| 15.4.1 | Principles of Coulometric Titrations | 112 |
| 15.4.2 | Advantages of Coulometric Titrations | 112 |
| 15.4.3 | Errors in Coulometric Titrations | 112 |
| 15.4 | Nature of Electrodes used in Coulometric Titrations | 113 |
| 15.5 | Applications of Coulometric Titrations | 113 |
| | Exercises | 115 |
| 16. | Polarography | |
| 16.1 | Introduction | 117 |
| 16.2 | The Instrument | 117 |
| 16.3 | Factors Affecting Current-voltage Curves | 119 |
| 16.4 | Half Wave Potentials | 121 |
| 16.5 | Applications of Polarography | 122 |
| | Exercises | 123 |
| 17. | Amperometric titrations | 125 |
| 17.1 | Introduction | 125 |
| 17.2 | Apparatus for Amperometric Titrations | 125 |
| 17.3 | End point in Amperometric Titrations | 128 |
| 17.4 | Advantages of Amperometric Titrations | 129 |
| 17.5 | Disadvantages of Amperometric Titrations | 130 |
| 17.6 | Applications of Amperometric Titrations | 130 |
| 17.7 | Amperometric Titrations with Two Indicator Electrodes | 132 |
| | Exercises | 133 |
| 18. | Potentiometric titrations | 135 |
| 18.1 | Introduction | 135 |
| 18.2 | Principle of Potentiometric Titration | 136 |
| 18.3 | Indicator Electrode | 137 |
| 18.4 | Reference Electrodes | 138 |
| 18.5 | Apparatus for Potentiometric Titrations | 139 |
| 18.6 | Applications of Potentiometric Titrations | 140 |
| 18.6.1 | Neutralisation Titrations | 140 |
| 18.6.2 | Oxidation-reduction Titrations | 141 |
| 18.6.3 | Precipitation Titrations | 143 |

| | | |
|------------|--|------------|
| 18.6.4 | Complexometric Titrations | 144 |
| 18.7 | Differential Titrations | 144 |
| 18.8 | Automatic Titrations | 145 |
| 18.9 | Advantages of Potentiometric Titrations | 145 |
| | Exercises | 146 |
| 19. | Spectrophotometric Titrations | 147 |
| 19.1 | Introduction | 147 |
| 19.2 | Procedure of Titration | 148 |
| 19.3 | Applications | 149 |
| | Exercises | 150 |
| 20. | High Frequency Titrations | 151 |
| 20.1 | Introduction | 151 |
| 20.2 | Instrument | 151 |
| 20.3 | High Frequency Titrations | 153 |
| 20.4 | Applications of High Frequency Methods | 154 |
| 20.4.1 | Acid-Base Titrations | 154 |
| 20.4.2 | Measurement of Dielectric Constant | 154 |
| 20.4.3 | Analysis of Binary Mixtures | 156 |
| 20.4.4 | Complexometric Titrations | 156 |
| 20.5 | Advantages of High Frequency Titrations | 156 |
| | Exercises | 156 |
| 21. | pH Measurements | 159 |
| 21.1 | Introduction | 159 |
| 21.2 | Determination of pH of a Solution by Potentiometry | 161 |
| 21.2.1 | Determination of pH using Hydrogen Electrode | 161 |
| 21.2.2 | Determination of pH using Glass Electrode | 163 |
| 21.2.3 | Determination of pH using Quinhydrone Electrode | 165 |
| 21.3 | Determination of pH Using a pH Meter | 167 |
| 21.4 | Determination of pH using pH indicators | 168 |
| | Exercises | 169 |
| 22. | Calorimetry | 171 |
| 22.1 | Introduction | 171 |
| 22.2 | Principle of Calorimeter | 173 |
| 22.3 | Procedure for the estimation of Cu ²⁺ in a unknown solution | 173 |
| | Exercises | 176 |

| | | |
|---|---------------|------------|
| | PART V | |
| (Instrumental Method for Structure Determination of Organic Compounds) | | |
| 23. Infrared spectroscopy | | 179 |
| 23.1 Introduction | | 179 |
| 23.2 Basic Theory | | 181 |
| 23.3 Instrumentation | | 181 |
| 23.4 Fourier Transform Infrared (FTIR) Spectrometer | | 182 |
| 23.4 (A) Principle of Interferometry | | 183 |
| 23.5 Mode of Vibrations | | 183 |
| 23.5 (a) Number of Fundamental Vibrations, Selection Rules | | 184 |
| 23.6 Recording of IR Spectra | | 185 |
| 23.7 Major Bands in the IR Spectra of Different Types of Organic Compounds | | 189 |
| 23.8 Interpretation of the Infrared Spectra | | 197 |
| 23.9 Applications of Infrared Spectroscopy | | 211 |
| 23.10 IR Spectras of Some Typical Compounds | | 214 |
| 23.11 Non-dispersive Infrared Spectroscopy | | 222 |
| Exercises | | 222 |
| 24. Ultraviolet spectroscopy | | 233 |
| 24.1 Introduction | | 233 |
| 24.2 Terms Used in UV Spectroscopy | | 235 |
| 24.3 Electronic Transitions | | 236 |
| 24.4 Ultraviolet Spectrometer | | 238 |
| 24.5 Characteristic Absorption of Organic Compounds | | 240 |
| 24.6 Interpretation of UV Spectra | | 261 |
| 24.7 Applications of UV Spectroscopy | | 261 |
| Exercises | | 265 |
| 25. Nuclear Magnetic Resonance (NMR) Spectroscopy | | 271 |
| 25.1 Proton Nuclear Magnetic Resonance (1H NMR or PMR) Spectroscopy | | 271 |
| 25.1.1 Introduction | | 271 |
| 25.1.2 The NMR Spectrometer | | 273 |
| 25.1.3 Interpretation of the 1H NMR Spectra | | 276 |
| 25.1.4 Chemical Shifts of Different Types of Protons | | 285 |
| 25.1.5 The Splitting of Signals | | 291 |
| 25.1.6 Final Interpreting an 1H NMR Spectra | | 303 |

| | | |
|------------|--|------------|
| 25.1.7 | Interpretation of the ^1H NMR Spectra of Some Simple Molecules | 306 |
| 25.1.8 | Predicting the ^1H NMR Spectrum of an Organic Compound | 308 |
| 25.1.9 | Complicated ^1H NMR Spectra | 309 |
| 25.1.10 | Applications of Proton Magnetic Resonance Spectroscopy | 317 |
| 25.2 | Carbon-13 NMR (^{13}C NMR) Spectroscopy | 321 |
| 25.2.1 | Introduction | 321 |
| 25.2.2 | Interpretation of ^{13}C NMR Spectra | 322 |
| 25.2.3 | Chemical Shift | 324 |
| 25.2.4 | Identification of Peaks in ^{13}C NMR Spectra on the Basis of Hybridization of Each Carbon Atom | 327 |
| 25.2.5 | Two-Dimensional (2D) ^{13}C NMR Spectroscopy | 330 |
| 25.2.6 | Applications of ^{13}C Spectra | 330 |
| | Exercises | 332 |
| 26. | Electron spin resonance (ESR) spectroscopy | 345 |
| 26.1 | Introduction | 345 |
| 26.2 | Instrument | 347 |
| 26.3 | Recording an ESR Spectra | 349 |
| 26.4 | Hyperfine Splitting | 351 |
| 26.4.1 | ESR Spectra of Hydrogen Atom | 351 |
| 26.4.2 | ESR Spectra of Deuterium | 352 |
| 26.4.3 | ESR Spectra of Methyl Radical | 354 |
| 26.5 | Determination of g-value | 354 |
| 26.6 | Line Width | 355 |
| 26.7 | Hyperfine structure in ESR spectra | 355 |
| 26.8 | Applications of ESR spectroscopy | 358 |
| 26.9 | Electron Nuclear Double Resonance (ENDOR) | 361 |
| 26.10 | Electron Double Resonance (ELDOR) | 361 |
| | Exercises | 361 |
| 27. | Mass spectrometry | 365 |
| 27.1 | Introduction | 365 |
| 27.2 | The Mass Spectrometer | 366 |
| 27.3 | The Mass Spectrum | 368 |
| 27.4 | Determination of Molecular Formula | 370 |

| | | |
|---------|--|-----|
| 27.4.1 | Molecular Formula from Isotopic Peaks | 370 |
| 27.4.2 | Molecular Formula Using High-Resolution Mass Spectrometry | 373 |
| 27.5 | Recognition of The Molecular ION Peak | 374 |
| 27.6 | Use of the Molecular Formula | 376 |
| 27.7 | Fragmentation | 377 |
| 27.7.1 | Fragmentation by Cleavage of a C—C Single Bond | 377 |
| 27.7.2 | Fragmentation by Cleavage of More than One Bond | 380 |
| 27.7.3 | Rearrangements | 382 |
| 27.8 | Mass spectra of some typical classes of compounds | 383 |
| 27.8.1 | Saturated Hydrocarbons | 383 |
| 27.8.2 | Unsaturated Hydrocarbons | 385 |
| 27.8.3 | Alcohols | 387 |
| 27.8.4 | Phenols | 390 |
| 27.8.5 | Ethers | 391 |
| 27.8.6 | Ketones | 392 |
| 27.8.7 | Aldehydes | 395 |
| 27.8.8 | Carboxylic Acids | 396 |
| 27.8.9 | Carboxylic Esters | 397 |
| 27.8.10 | Lactones | 399 |
| 27.8.11 | Amines | 400 |
| 27.8.12 | Amides | 401 |
| 27.8.13 | Nitro Compounds | 402 |
| 27.8.14 | Nitrites | 403 |
| 27.8.15 | Nitrates | 403 |
| 27.8.16 | Sulfur Containing Compounds | 403 |
| 27.8.17 | Compounds Containing Halogens | 404 |
| 27.8.18 | Heterocyclic Compounds | 406 |
| 27.9 | Gas Chromatography-Mass Spectrometry | 409 |
| 27.9.1 | Applications of Gas Chromatography-Mass Spectrometry | 409 |
| 27.10 | Negative ion Mass Spectrometry | 409 |
| 27.10.1 | Negative Ion Formation | 410 |
| 27.10.2 | Reactions Observed during Negative ion Chemical Ionization | 410 |
| 27.10.3 | Fragment Patterns of Negative Ions | 411 |

| | |
|---|------------|
| 27.10.4 Applications of Negative ion Mass Spectrometry | 415 |
| 27.11 Applications of Mass spectrometry | 417 |
| 27.11.1 Determination of Structure of Organic Compounds | 417 |
| 27.11.2 Determination of Molecular Weight and Molecular Formula | 417 |
| 27.11.3 Miscellaneous Applications | 418 |
| Exercises | 422 |
| 28. Polarimetry | 425 |
| 28.1 Introduction | 425 |
| 28.2 Plane Polarized Light | 425 |
| 28.3 Optical Activity | 426 |
| 28.4 Kinds of Molecules Analysed by Polarimetry | 427 |
| 28.5 Theoretical Considerations | 427 |
| 28.6 Polarimeter | 429 |
| 28.7 Applications of Polarimetry | 429 |
| Exercises | 433 |
| PART-VI | |
| (Instrumental Methods Analysis of Inorganic Compounds) | |
| 29. Microwave Spectroscopy | 437 |
| 29.1 Introduction | 437 |
| 29.2 Differences Between Microwave Spectroscopy and IR Spectroscopy | 438 |
| 29.3 Theory of Microwave Spectroscopy | 438 |
| 29.4 Diatomic Molecule as a Rigid Rotator | 438 |
| 29.5 Selection Rules for Rotational Spectra | 441 |
| 29.6 Instrument for Microwave Spectroscopy | 443 |
| 29.7 Applications | 445 |
| Exercises | 448 |
| 30. Nuclear Quadrupole Resonance (NQR) Spectroscopy | 451 |
| 30.1 Introduction | 451 |
| 30.2 Theory | 451 |
| 30.3 NQR Instrument | 453 |
| 30.4 Applications of NQR | 454 |
| Exercises | 456 |
| 31. Raman Spectroscopy | 457 |
| 31.1 Introduction | 457 |
| 31.2 Principle of Raman Spectroscopy | 457 |

| | |
|--|------------|
| 31.3 Characteristics of Raman Lines | 459 |
| 31.4 Differences between Raman Spectra and Infrared Spectra | 459 |
| 31.5 Polarizability | 460 |
| 31.6 Explanation of Mechanism of Raman Effect | 460 |
| 31.7 Raman Spectrometer | 463 |
| 31.8 Intensity of Raman Peaks | 464 |
| 31.9 Applications of Raman Spectroscopy | 464 |
| Exercises | 469 |
| 32. Mossbauer spectroscopy | 471 |
| 32.1 Introduction | 471 |
| 32.2 Mossbauer Effect | 471 |
| 32.3 Mossbauer Spectrometer | 472 |
| 32.4 Nuclides and their Characteristics | 474 |
| 32.5 Applications MossbaUer Spectroscopy | 474 |
| Exercises | 478 |
| 33. Emission spectroscopy | 481 |
| 33.1 Introduction | 481 |
| 33.2 Types of Spectra | 481 |
| 33.3 Comparison of Emission Spectroscopy with Flame Photometry | 482 |
| 33.4 Instrumentation | 483 |
| 33.5 Applications of Emission Spectroscopy | 488 |
| Exercises | 490 |
| PART VII | |
| (Miscellaneous Instrumental Methods) | |
| 34. Atomic absorption spectroscopy (AAS) | 493 |
| 34.1 Introduction | 493 |
| 34.2 The Instrument and Procedure of Estimation | 494 |
| 34.3 Determination of the Concentration of element iN ppm | 497 |
| 34.4 Double Beam Atomic Absorption Spectrometer | 498 |
| 34.5 Atomic Absorption Spectroscopy Versus Flame Emission Spectroscopy | 498 |
| 34.6 Interference | 499 |
| 34.6.1 Chemical Interference | 499 |
| 34.6.2 Solvent Interference | 499 |
| 34.7 Advantages of Atomic Absorption Spectroscopy | 499 |
| 34.8 Applications of Atomic Absorption Spectroscopy | 500 |

| | | |
|------------|--|------------|
| 34.9 | Flameless Atomic Absorption Method | 504 |
| | Exercises | 504 |
| 35. | Flame photometry | 505 |
| 35.1 | Introduction | 505 |
| 35.2 | Principle of Flame Photometry | 505 |
| 35.3 | Components of a Flame Photometer | 507 |
| 35.4 | Selection of appropriate solvent for dissolving the salt in flame photometry | 511 |
| 35.5 | Instrument | 511 |
| | 35.5.1 Simple Flame Photometer | 511 |
| | 35.5.2 Internal Standard Flame Photometer | 512 |
| 35.6 | Techniques of Analysis | 513 |
| | 35.6.1 Analysis Involving Calibration Curves | 513 |
| | 35.6.2 Analysis Involving Internal Standard | 513 |
| | 35.6.3 Analysis Involving Addition of Standard | 513 |
| 35.7 | Preparation of Standard Solutions | 513 |
| 35.8 | Interferences in Flame Photometry | 514 |
| 35.9 | Factors which affect intensity of emitted radiation | 515 |
| 35.10 | Limitations of Flame Photometry | 516 |
| 35.11 | Applications of Flame Photometry | 516 |
| | Exercises | 517 |
| 36. | Fluorimetry and phosphorimetry | 519 |
| 36.1 | Introduction | 519 |
| 36.2 | Fluorescence and Absorption Method | 520 |
| 36.3 | Fluoremetry and Phosphorimetry | 520 |
| 36.4 | Theory | 520 |
| | 36.4.1 Relation between Fluorescence Intensity and Concentration | 522 |
| 36.5 | Types of Transitions in Fluorescence | 522 |
| 36.6 | Instrumentation | 523 |
| | 36.6.1 Instrument for Fluorimetric Analysis | 523 |
| | 36.6.2 Instrument for Phosphorimetric Analysis | 525 |
| 36.7 | Applications of Fluorimetry | 526 |
| 36.8 | Applications of Phosphorimetry | 529 |
| 36.9 | Comparison of Fluorimetry and Phosphorimetry | 529 |
| | Exercises | 530 |

| | |
|--|------------|
| 37. Nephelometric and Turbidimetric Techniques | 531 |
| 37.1 Introduction | 531 |
| 37.2 Turbidimetry and Colorimetry | 532 |
| 37.3 Nephelometry and Fluorimetry | 532 |
| 37.4 Choice between Nephelometry and Turbidimetry | 532 |
| 37.5 Basic Principles of Nephelometry and Turbidimetry | 532 |
| 37.6 Instrumentation | 534 |
| 37.6.1 Turbidimeters | 536 |
| 37.6.2 Nephelometers | 536 |
| 37.7 Applications | 537 |
| Exercises | 540 |
| 38. Refractometry and interferometry | 541 |
| 38.1 Introduction | 541 |
| 38.2 Specific Rotation | 542 |
| 38.3 Molar Refraction | 542 |
| 38.4 Determination of Refractive Index | 544 |
| 38.5 Applications of Refractometry | 545 |
| 38.6 Optical Exaltation | 546 |
| 38.7 Interferometry | 547 |
| 38.7.1 Applications of Interferometer | 549 |
| Exercises | 549 |
| 39. X-ray methods | 551 |
| 39.1 Introduction | 551 |
| 39.2 Theoretical Consideration | 551 |
| 39.3 Instrumentation | 554 |
| 39.4 Instrument for X-ray Absorption | 557 |
| 39.5 Instrument for X-ray Diffraction | 558 |
| 39.5.1 Laue Method | 558 |
| 39.5.2 Rotating Crystal Method | 559 |
| 39.6 Application of X-ray Diffraction | 559 |
| 39.7 X-ray Fluorescence | 563 |
| 39.7.1 Instrumentation | 564 |
| 39.7.2 Applications of X-ray Fluorescence Spectroscopy | 564 |
| Exercises | 565 |
| Index | 567 |