INTERNATIONAL MULTI DISCIPLINARY JOURNAL FOR RESEARCH & DEVELOPMENT
eISSN 2394-6334 Impact factor: 7,854 Volume 12, issue 12 (2025)

POLARIMETRIC ANALYSIS: PRINCIPLES, INSTRUMENTATION, AND APPLICATIONS IN PHARMACEUTICAL ANALYSIS

Obidov Dilmurod Xomidjon ugli
Asisstent at pharmaceutical department
At Andijane State Medical Institute

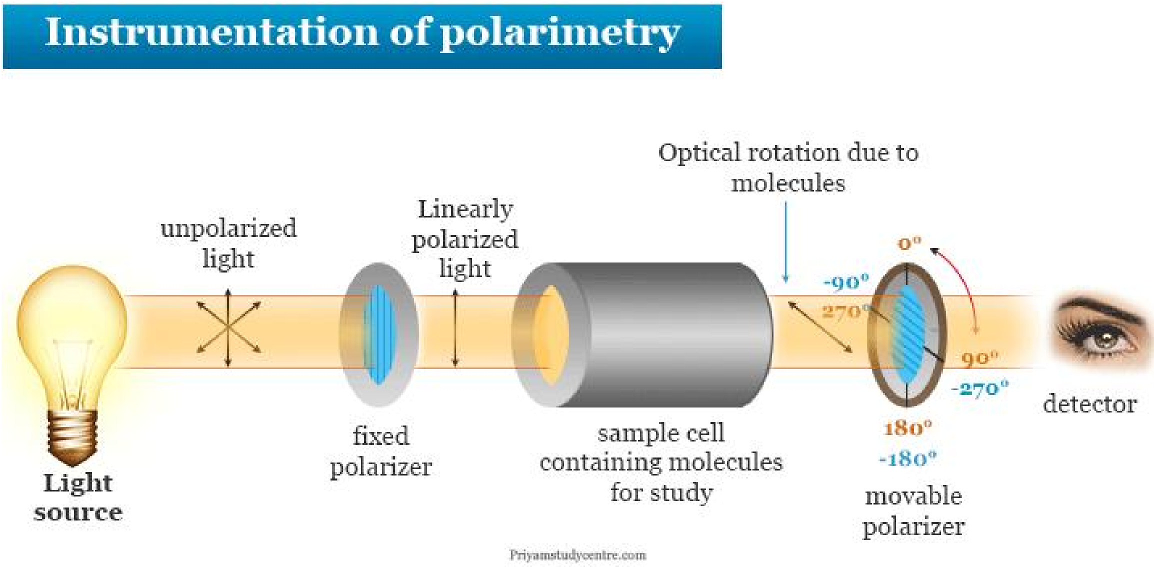
Abstract: Polarimetric analysis is a classical physicochemical analytical technique based on the measurement of optical rotation produced by optically active substances when plane-polarized light passes through them. This method plays a significant role in pharmaceutical, chemical, and biochemical analysis, particularly in the study of chiral compounds such as carbohydrates, amino acids, alkaloids, and certain active pharmaceutical ingredients. Due to its simplicity, non-destructive nature, and relatively high reproducibility, polarimetry is widely applied in routine quality control and raw material testing. This article presents an in-depth discussion of the theoretical background of polarimetry, the construction and operation of polarimetric instruments, analytical procedures, and the major applications, advantages, and limitations of the method in pharmaceutical analysis.

Keywords: Polarimetry; Optical rotation; Chiral compounds; Pharmaceutical analysis; Quality control

Introduction. The increasing complexity of pharmaceutical substances and formulations has intensified the need for reliable and selective analytical methods capable of ensuring drug quality, safety, and efficacy. Many pharmaceutical compounds exist in optically active forms, where stereochemistry plays a critical role in biological activity and therapeutic performance. As a result, analytical techniques that can characterize optical activity are of particular importance. Polarimetric analysis is one of the oldest and most established optical methods used to investigate chiral substances. Despite the development of advanced spectroscopic and chromatographic techniques, polarimetry remains relevant due to its operational simplicity, cost-effectiveness, and direct relationship between optical rotation and molecular structure. In pharmaceutical laboratories, polarimetry is routinely employed for identity testing, purity assessment, and quantitative determination of optically active compounds.

Theoretical Principles of Polarimetry. Polarimetric analysis is based on the phenomenon of optical activity, which refers to the ability of certain substances to rotate the plane of polarized light. When unpolarized light passes through a polarizer, it becomes plane-polarized, vibrating in a single plane. Upon passing through an optically active medium, this plane of polarization is rotated either clockwise (dextrorotatory, +) or counterclockwise (levorotatory, −). The angle of rotation (α) depends on several parameters, including the nature of the substance, its concentration, the path length of the sample cell, the wavelength of light, and temperature. To standardize measurements, the concept of specific rotation is used, which represents the intrinsic optical property of a substance independent of sample dimensions. In pharmaceutical practice, measurements are typically carried out at 20 °C using monochromatic light corresponding to the sodium D-line (589 nm).

Instrumentation. The primary instrument used in polarimetric analysis is the polarimeter. A classical polarimeter consists of a light source, a polarizer to produce plane-polarized light, a sample tube of known length, an analyzer, and an optical detection system. The sample tube is filled with the test solution and placed in the optical path, where the rotation of polarized light is measured. Modern digital polarimeters have significantly improved the precision and ease of use of the technique. These instruments are equipped with automatic temperature control, electronic detectors, and digital displays that provide direct readings of optical rotation or specific rotation. Digital polarimeters minimize operator-dependent errors and are particularly advantageous for routine pharmaceutical quality control and regulatory compliance.



Analytical Procedure. The polarimetric analytical procedure is relatively simple and requires minimal sample preparation. Prior to analysis, the instrument is calibrated using distilled water or certified reference standards with known optical rotation values. The sample solution is prepared at a defined concentration and introduced into a clean polarimeter tube, ensuring the absence of air bubbles or impurities. After temperature equilibration, the optical rotation is measured and recorded. For quantitative analysis, the measured rotation is used to calculate the concentration of the optically active substance using the specific rotation equation, or alternatively, a calibration curve may be employed. Due to its rapid measurement time, polarimetry is well suited for routine analysis in pharmaceutical laboratories.

Applications in Pharmaceutical Analysis. Polarimetric analysis is widely used in the pharmaceutical industry for the evaluation of optically active substances. It is particularly important in the analysis of carbohydrates such as glucose, fructose, sucrose, and lactose, which are commonly used as excipients or active ingredients. The method is also applied to amino acids, antibiotics, steroids, and alkaloids that exhibit optical activity. In addition to quantitative determination, polarimetry is valuable for detecting adulteration, assessing enantiomeric purity, and monitoring batch-to-batch consistency of raw materials. Furthermore, polarimetric measurements can be used to control manufacturing processes involving fermentation or enzymatic reactions, where changes in optical rotation reflect chemical transformations.

Advantages and Limitations. One of the major advantages of polarimetric analysis is its non-destructive nature, allowing samples to be analyzed without chemical modification. The method is rapid, relatively inexpensive, and requires only simple instrumentation compared to advanced analytical techniques. High reproducibility can be achieved under controlled temperature and wavelength conditions. However, polarimetry also has limitations. It is applicable only to optically active substances and lacks selectivity in multi-component systems where several chiral compounds may contribute to the observed rotation. Additionally, colored, opaque, or turbid samples can interfere with accurate light transmission, reducing measurement reliability. These factors must be considered when selecting polarimetry as an analytical method.

Conclusion. Polarimetric analysis remains an important and reliable analytical technique in pharmaceutical science, particularly for the characterization and quantification of optically active compounds. Its simplicity, speed, and cost-effectiveness make it an attractive option for routine quality control and raw material testing. Advances in digital polarimeter technology have further enhanced the accuracy and practicality of this method in modern pharmaceutical laboratories. Although polarimetry has inherent limitations, it continues to serve as a valuable complementary technique alongside chromatographic and spectroscopic methods in pharmaceutical analysis.

References:

1. Xomidjon o‘g‘li O. D. Gas Chromatography: Theoretical Principles and Applications in Pharmaceutical Analysis //Journal of Modern Educational Achievements. – 2025. – T. 5. – №. 5. – C. 35-41.

2. Xolmatov J. O. ANALYTICAL METHOD DEVELOPMENT FOR PHARMACEUTICAL SOLUTIONS //Экономика и социум. – 2025. – №. 5-1 (132). – С. 866-869.

3. Mamatisakova G. A. et al. FROM PHARMACEUTICAL PROPERTIES OF BISMUTH DRUGS TO CLINICAL EFFICACY //Bulletin of Pure & Applied Sciences-Zoology. – 2024. – T. 43.

4. Skoog, D.A., Holler, F.J. and Crouch, S.R. (2014) Principles of Instrumental Analysis. 6th edn. Belmont, CA: Cengage Learning. https://doi.org/10.1007/978-1-4614-1789-8

5. Mendham, J., Denney, R.C., Barnes, J.D. and Thomas, M.J.K. (2000) Vogel’s Textbook of Quantitative Chemical Analysis. 6th edn. Harlow: Pearson Education. https://doi.org/10.1002/9780470141961

6. Shrivastava, A. and Gupta, V.B. (2011) ‘Analytical methods for optical rotation and polarimetric measurements’, Journal of Chemical Education, 88(6), pp. 769–773. https://doi.org/10.1021/ed100657p

7. Eliel, E.L. and Wilen, S.H. (1994) Stereochemistry of Organic Compounds. New York: Wiley. https://doi.org/10.1002/9780470171787

8. Gal, J. (2013) ‘Louis Pasteur, language, and molecular chirality I. Background and initial developments’, Chirality, 25(2), pp. 65–72. https://doi.org/10.1002/chir.22110

9. Ermer, J. and Miller, J.H. McB. (2005) Method Validation in Pharmaceutical Analysis. Weinheim: Wiley-VCH. https://doi.org/10.1002/3527604689

10. United States Pharmacopeial Convention (2023) USP–NF, General Chapter <781> Optical Rotation. Rockville, MD: USP. https://doi.org/10.31003/USPNF_M781

11. European Pharmacopoeia Commission (2023) European Pharmacopoeia, General methods: Optical rotation. Strasbourg: Council of Europe. https://