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CAPILLARY ELECTROPHORESIS AND IT'S ROLE IN PHARMACEUTICAL INDUSTRY

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ABSTRACT

Capillary electrophoresis (CE) is a cutting-edge analytical technique that separates ionic species based on their electrophoretic mobility using an electric field within a capillary tube. This method has gained prominence since its development in the 1980s, owing to its high resolution, rapid analysis times, minimal sample requirements, and versatile applications. The fundamental concept of CE involves the application of a high-voltage electric field across a narrow capillary filled with an electrolyte solution. It offers several modes such as capillary zone electrophoresis (CZE), capillary gel electrophoresis (CGE), capillary isoelectric focusing (CIEF), and micellar electrokinetic chromatography (MEKC), each suited for specific types of analyses. This article provides an in-depth look at the principles of CE, its broad range of applications, and its significant contributions to scientific research and industry.

Key Word: Capillary Electrophoresis (CE).

INTRODUCTION

Capillary electrophoresis (CE) is an analytical separation technique that uses the principles of electrophoresis in a capillary format. This causes charged analytes to migrate at different velocities depending on their charge-to-mass ratio, allowing their separation. Capillary electrophoresis (CE) is an analytical technique that separates ions based on their electrophoretic mobility using an electric field. Developed in the 1980s, CE has since become a powerful tool in various fields due to its high efficiency, speed, and the ability to handle small sample volumes. The method employs narrow-bore capillaries filled with a conductive buffer solution, allowing the separation of charged species. The technique is versatile, accommodating different modes such as capillary zone electrophoresis (CZE), capillary gel electrophoresis (CGE), capillary isoelectric focusing (CIEF), and micellar electrokinetic chromatography (MEKC). Developed in the early 1980s by Jorgenson and Lukacs, CE was initially a response to the need for a high-resolution technique that could handle small sample volumes with fast analysis times. The technique quickly evolved, incorporating various modes to enhance its versatility. CE's narrow capillaries (typically 25-100 µm in internal diameter) and the use of high electric fields (typically 10-30 kV) result in efficient heat dissipation, enabling high-resolution separations that are not achievable with traditional electrophoresis methods. Capillary Electrophoresis can be performed in several modes, including:

Capillary Zone Electrophoresis (CZE): The simplest form, where separation is based purely on differences in electrophoretic mobility.
Capillary Gel Electrophoresis (CGE): Utilizes a gel-filled capillary to separate macromolecules like proteins and nucleic acids based on size.
Capillary Isoelectric Focusing (CIEF): Separates amphoteric molecules like proteins based on their isoelectric points.
Micellar Electrokinetic Chromatography (MEKC): Uses micelles to separate neutral molecules based on their partitioning between the micelle and the aqueous phase.

PRINCIPLE

Capillary electrophoresis (CE) operates on the principle of separating charged molecules based on their electrophoretic mobility in an electric field within a narrow capillary filled with a conductive buffer solution. When an electric current is applied across the capillary, ions and charged molecules migrate towards the electrode of opposite charge. The rate of migration, or electrophoretic mobility, depends on the charge and size of the molecules, as well as the strength of the electric field and the viscosity of the buffer solution. By controlling these parameters, CE can achieve highly efficient separations of analytes ranging from small ions to large biomolecules like proteins and nucleic acids, making it a versatile technique in analytical chemistry and biochemistry.

INSRTUMENTATION OF CAPILLARY ELECTROPHORESIS

The instrumentation of capillary electrophoresis includes a high-voltage power supply to generate the electric field, a capillary tube (typically made of fused silica) through which the sample travels, an injection system for introducing the sample, a detector to monitor the separated components, and a data acquisition system for analysis and interpretation of results.

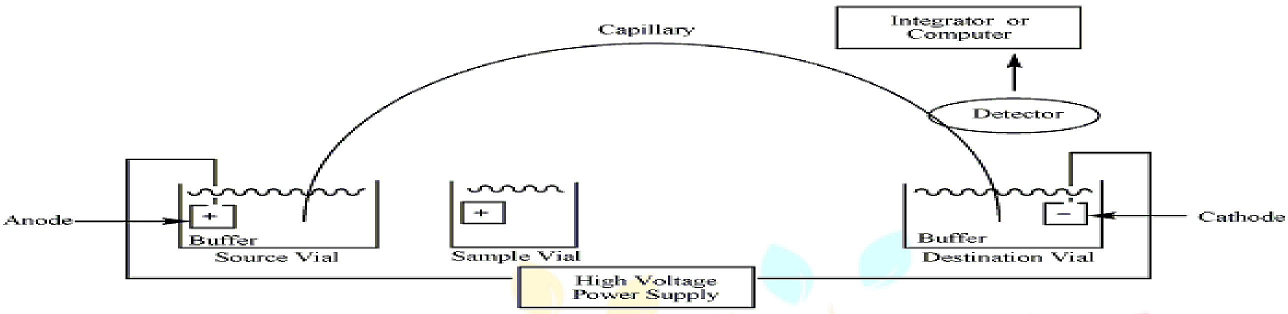

Figure:1 **Capillary Electrophoresis**

The steps in capillary electrophoresis typically include:

1.Sample Preparation: The sample is prepared by dissolving it in a suitable buffer solution.

2.Injection: The sample is introduced into the capillary tube, usually through electrokinetic injection or pressure injection.

3.Separation: An electric field is applied along the length of the capillary tube. This causes the charged components of the sample to migrate through the capillary at different speeds based on their charge-to-size ratio.

4.Detection: As the components separate, they pass a detector (such as UV-Vis absorbance detector, fluorescence detector, or mass spectrometer) which detects them based on their characteristic properties.

5.Data Analysis: The detector output is recorded and analysed to determine the identity and quantity of each separated component.

These steps are crucial for performing capillary electrophoresis and obtaining meaningful analytical results.

MODES OF CAPILLARY ELECTROPHORESIS

Capillary electrophoresis (CE) is a versatile analytical technique that separates ions and molecules based on their electrophoretic mobility in an electric field within a small capillary filled with electrolyte. There are several modes of capillary electrophoresis, each tailored to specific types of analytes and analytical requirements:

1.**Capillary Zone Electrophoresis (CZE)**: This is the most common mode where analytes are separated based on differences in their electrophoretic mobility in a buffer solution. It's suitable for separating small ions, peptides, and small proteins.

2.Micellar Electrokinetic Chromatography (MEKC): In MEKC, a surfactant is added to the buffer to form micelles, which can interact with analytes based on hydrophobic interactions in addition to electrophoretic mobility. It's useful for separating neutral and charged compounds with varying hydrophobicity.

3.Capillary Electrochromatography (CEC): CEC combines the principles of electrophoresis and chromatography by using a stationary phase (typically a porous material) inside the capillary. Analytes are separated based on both electrophoretic mobility and interactions with the stationary phase.

4.Capillary Isotachophoresis (CITP): Separates ions based on differences in their ionic mobilities and their concentration-dependent zone formation. Often used for preconcentration and separation of ions and small molecules with similar charges.

5.Capillary Isoelectric Focusing (CIEF): CIEF separates analytes based on their isoelectric points, focusing them into sharp bands along the capillary where the pH gradient is established. It's often used for analyzing proteins and peptides based on their charge differences.

6.Capillary Gel Electrophoresis (CGE): CGE utilizes a viscous polymer solution (gel) as the separation medium within the capillary. It separates analytes based on size and shape, making it suitable for separating large molecules such as proteins and nucleic acids.

Each mode of capillary electrophoresis offers distinct advantages and is chosen based on the specific characteristics of the analytes and the desired separation conditions. The versatility of CE makes it a powerful technique in analytical chemistry, biochemistry, and molecular biology.

CAPILLARY ELECTROPHORESIS OFFERS SEVERAL ADVANTAGES AND DISADVANTAGES

Advantages:

1.High Resolution: CE can achieve very high resolution due to the efficiency of separation in the thin capillary column, allowing for the separation of complex mixtures with closely related analytes.

2.Small Sample Size: CE requires only small amounts of sample and reagents, making it suitable for analyses where sample availability is limited.

3.Speed: CE can provide rapid analyses, with separations often completed within minutes to hours, depending on the complexity of the sample.

4.Automation: CE systems can be automated, reducing human error and increasing reproducibility of results.

5.Versatility: It can analyze a wide range of analytes, including small molecules, proteins, nucleic acids, and ions, making it versatile in various fields such as pharmaceuticals, biochemistry, and environmental monitoring.

6.Quantitative and Qualitative Analysis: CE can be used for both quantitative (determining concentrations) and qualitative (identifying components) analyses.

Disadvantages:

1.Sensitivity to Operating Conditions: CE can be sensitive to changes in temperature, pH, and buffer composition, which can affect reproducibility and accuracy of results.

2.Limited Sample Compatibility: Some samples may require extensive pretreatment to be compatible with CE, which can be time-consuming and may alter sample integrity.

3.Detection Limitations: Detection limits in CE can vary depending on the analyte and detection method used, and may not always match those achievable by other techniques like HPLC or GC.

4.Instrument Complexity: CE instrumentation can be complex and require specialized training to operate and maintain, which may pose a barrier in some settings.

5.Peak Overlapping: In complex samples, peak overlapping can occur, reducing the ability to resolve all components distinctly.

6.Matrix Effects: Similar to other analytical techniques, CE can be affected by matrix effects from sample components that interfere with separation and detection.

Understanding these advantages and disadvantages helps in choosing the appropriate analytical technique based on the specific requirements of the analysis and the characteristics of the sample.

APPLICATIONS

1.Pharmaceutical Analysis

Drug Purity and Impurity Profiling: CE is extensively used for the analysis of pharmaceutical compounds, ensuring drug purity and identifying impurities. Its high resolution and sensitivity make it ideal for compliance with regulatory standards.

Chiral Separation: CE can separate enantiomers of chiral drugs, which is crucial for the development and quality control of pharmaceuticals, as different enantiomers can have different therapeutic effects and safety profiles.

2.Biotechnology and Proteomics

Protein and Peptide Analysis: CE is employed to analyze proteins and peptides, offering high-resolution separation and the ability to handle complex biological matrices. It is particularly useful for protein characterization, including the determination of molecular weights and the identification of post-translational modifications.

DNA Sequencing and Genotyping: CE is a cornerstone in DNA sequencing, notably used in the Sanger sequencing method. It also plays a role in genotyping, aiding in the detection of genetic variations such as single nucleotide polymorphisms (SNPs) and short tandem repeats (STRs).

3.Environmental Analysis

Pollutant Detection: CE is utilized to detect and quantify environmental pollutants, including heavy metals, pesticides, and organic compounds. Its ability to separate and identify multiple analytes in complex samples makes it invaluable for monitoring water and soil quality.

Food Safety: In the food industry, CE is applied to ensure safety and compliance by detecting contaminants, additives, and naturally occurring toxins. It can analyze food matrices efficiently, providing accurate and reliable results.

4.Clinical Diagnostics

Disease Biomarkers: CE is used in clinical diagnostics to identify and quantify biomarkers for various diseases, including cancer and metabolic disorders. It helps in the early detection and monitoring of disease progression.

Electrolyte Balance: The technique is employed to measure electrolytes in biological fluids, essential for diagnosing and managing conditions like electrolyte imbalances and renal disorders.

CONCLUSION

Capillary electrophoresis has revolutionized analytical science with its versatility, high resolution, and efficiency. Its applications span across numerous fields including pharmaceuticals, biotechnology, environmental science, and clinical diagnostics. The technique continues to evolve, driven by advancements in technology and methodology, thereby broadening its scope and enhancing its capabilities. As a result, CE remains a vital tool in both research and industry, contributing significantly to scientific and technological progress.

REFERENCES

1.Altria, K.D. (1999). Overview of capillary electrophoresis and its applications. Journal of Chromatography A, 856(1-2), 443-463.

2.Dolnik, V., & Liu, S. (2005). Applications of capillary electrophoresis on microchip. Journal of Separation Science, 28**(**15), 1994-2009.

3.Thormann, W., & Mosher, R.A. (1991). Capillary Electrophoresis of Proteins and Peptides: Past, Present, and Future**.** Electrophoresis, 12**(**10), 501-513.

4.Landers, J.P. (2008). Handbook of Capillary and Microchip Electrophoresis and Associated Micro techniques**.** CRC Press.

5.Breadmore, M.C., Thabano, J.R., Dawod, M., Kazarian, A.A., & Quirino, J.P. (2009). Recent advances in enhancing the sensitivity of electrophoresis and electrochromatography in capillaries and microchips (2006–2008). Electrophoresis, 30(1), 230-248.

6. Li, Sam. Capillary Electrophoresis: Principles, instrumentation Journal of Chromatography Library; Elsevier Science Publishers: The Netherlands, 1992; Vol 52.