Analytical Techniques in Forensic Science: Spectroscopy and Chromatography

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EXECUTIVE SUMMARY

Spectroscopy and chromatography are two fundamental analytical techniques widely used in scientific research, industrial applications, and various fields of study, including chemistry, biology, environmental science, and forensic science. Spectroscopy involves the interaction of matter with electromagnetic radiation, allowing the characterization of molecules based on their absorption, emission, or scattering of light. Chromatography, on the other hand, is a separation technique that separates and analyzes mixtures based on differences in their distribution between a mobile phase and a stationary phase. This abstract provides an overview of the principles, methodologies, and applications of spectroscopy and chromatography. It highlights their significance in elucidating the chemical composition, structure, and properties of substances, as well as their roles in qualitative and quantitative analysis, detection of impurities, and identification of compounds in complex matrices.

PART A: SPECTROSCOPY

Spectroscopy is a diverse and indispensable field of scientific study that involves the measurement and analysis of interactions between matter and electromagnetic radiation (Tkachenko, 2006). By breaking down light into its constituent colours or examining how matter interacts with different wavelengths of radiation, spectroscopy provides critical insights into the composition, structure, and behaviour of molecules, atoms, and materials (Hollas, 2004).

Forensic Aspects of Spectroscopy

1. Identification of substances: Spectroscopic techniques such as infrared spectroscopy (IR), ultraviolet-visible spectroscopy (UV-Vis), nuclear magnetic resonance (NMR) spectroscopy, and mass spectrometry (MS) are commonly used in forensic science to identify unknown substances found at crime scenes or on evidence.
2. Analysis of trace evidence: Spectroscopic methods are sensitive enough to analyse trace amounts of substances, making them valuable for examining microscopic particles, fibres, paints, and other materials that could provide crucial evidence in criminal investigations (Lepot et al., 2008).
3. Drug analysis: Forensic spectroscopy plays a significant role in the identification and quantification of illicit drugs, pharmaceuticals, and other controlled substance (Weber et al., 2023). Techniques such as Raman spectroscopy and chromatography coupled with spectroscopic detection are commonly used in drug analysis.
4. Explosives detection: Spectroscopic techniques, particularly Raman spectroscopy, are employed in the detection and identification of explosive materials. These methods can rapidly analyze suspicious substances to determine if they contain explosive compounds.
5. Firearm residue analysis: Spectroscopic techniques like scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM-EDS) are used to analyze gunshot residue (GSR) left on individuals or surfaces after the discharge of firearms, aiding in the investigation of shootings.
6. Forensic imaging: Spectroscopic imaging techniques, such as infrared imaging and hyperspectral imaging, enable visualization of latent prints, bloodstains, and other evidence not easily visible to the naked eye, enhancing the detection and analysis of forensic evidence.
7. Authentication of documents and artworks: Spectroscopic methods are utilized to analyze the chemical composition of inks, pigments, and other materials used in documents, paintings, and artworks, assisting in the authentication process and the detection of forgeries.
8. Toxicology: Spectroscopic techniques are employed in toxicological analyses to identify and quantify toxic substances in biological samples such as blood, urine, and tissue, aiding in determining the cause of death or investigating cases of poisoning (Gill et al., 1982).