Synthesis of pH-Responsive Nanoscale Coacervates (pH Beads)

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pH strips are widely employed for rapid and low-cost pH determination. However, their single-use design contributes significantly to global laboratory waste. Absorbent paper also results in sample loss. This novel study investigates the encapsulation of pH-sensitive dyes within peptide-based coacervates as a scalable, low-cost, and reusable alternative to pH strips. Coacervates were formed via electrostatic complexation between anionic decapeptides of aspartic acid (D10) and cationic decapeptides of arginine (R10) in an 8.0 pH phosphate buffer. 18 distinct formulations of varying peptide solution volumes were curated based on turbidity and morphology, and eventually loaded with Litmus and Thymol Blue dyes. Prior to dye encapsulation, coacervate stability was significantly reinforced by the addition of tannic acid, whose multivalent phenolic groups facilitate intermolecular crosslinking primarily through hydrogen bonding. Thymol Blue was observed to disrupt coacervate formation, likely due to its anionic character and competitive interactions with cationic peptide residues, which interfere with charge-driven phase separation. In contrast, Litmus exhibited improved compatibility and broader pH responsiveness. Additionally, dye encapsulation following stable coacervate formation, rather than during it, yielded optimal structure. The optimized formulation demonstrated consistent colorimetric responses across the entire standard pH range for up to 15 reuse cycles. This innovative work establishes peptide-based coacervates ("pH Beads") as a sustainable alternative to conventional pH indicators by overcoming their single-use and sample-loss limitations. Potential applications include laboratory analytics, medical systems, and environmental and chemical process monitoring.

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