Flow Chemistry Case Studies

This document highlights a series of innovative studies demonstrating the capabilities, efficiency and safety advantages of continuous-flow technology across pharmaceutical, fine chemical and photochemical applications.

Taylor-Vortex Membrane Reactor for Continuous Gas–Liquid Reactions

A novel Taylor-vortex membrane reactor (TVMR) design is introduced, engineered for highly efficient continuous gas–liquid processing. The system features a cylindrical rotor housed within a stationary vessel and surrounded by a flexible set of equispaced baffle rings. This arrangement narrows the annular gap, dividing the reactor into eighteen discrete mixing zones. A 6-metre PFA tubular membrane is woven around the rotor, supported by the baffles, enabling a unique combination of dynamic mixing and membrane-based gas transfer.

Eight-Step Continuous-Flow Total Synthesis of Vitamin B1

This study presents a fully integrated eight-step continuous-flow route to vitamin B1, starting from commercially available 2-cyanoacetamide. The process demonstrates major improvements in performance and safety when compared with traditional batch manufacture. Key challenges—including mixing behaviour, unexpected clogging, solvent transitions, exothermicity and mitigation of undesired side reactions—were addressed through precise control using micro-channel reactors, mixers, separators and continuous filtration. The flow process delivered vitamin B1 with a 47.7% isolated yield at high purity, with a total residence time of approximately 3.5 hours, showcasing the significant green-chemistry benefits of continuous technology.

A Scalable Balz–Schiemann Reaction in Continuous Flow

To meet growing demand for aromatic fluorides, this work outlines a kilogram-scale continuous Balz–Schiemann process that eliminates the need to isolate hazardous diazonium salts. Diazotisation is performed at 10 °C with a 10-minute residence time, followed by rapid fluorination at 60 °C completed in only 5.4 seconds, achieving yields around 70%. By integrating these steps, reaction times are dramatically reduced and safety risks inherent in large-scale diazonium handling are significantly mitigated.

Horizontal Dynamically Mixed Flow Reactor for Photochemical Wohl–Ziegler Bromination

A 20 mL dynamically mixed Autichem DART photochemical reactor was evaluated for scale-up of the Wohl–Ziegler bromination of ethyl 4-methylbenzoate. Equipped with four custom 400 nm Kessil PR160L lamps, the reactor provides intensified mixing and consistent photonic efficiency. The study demonstrates a successful scale-up workflow transitioning from initial screening with an LED illuminator to continuous photochemical production suitable for 500 g-scale batches.

High-Throughput Exploration of a Thioxanthone-Catalysed Photoredox C–O Coupling

Using high-throughput experimentation and Design of Experiments methodologies, an efficient visible-light-mediated etherification process was developed using thioxanthen-9-one as a photocatalyst and a readily available nickel source. The approach identified mild, robust, and cost-effective conditions suitable for industrial application. The method was validated both in parallel synthesis and at larger scales, including an 83 mmol run using standard laboratory photochemical equipment.

Ruthenium-Catalysed Ester Reductions for Pharmaceutical Intermediates

Ruthenium pincer complexes were synthesised and optimised for catalytic ester reductions under mild hydrogen pressures of approximately 5 bar. Experimental design techniques were applied to refine reaction

conditions for yield, purity and robustness. Mechanistic insights were gained through intermediate identification, side-product analysis and time-course studies. The final optimised process was successfully demonstrated at scale in both batch and continuous-flow reactors.

Kilogram-Scale Plug-Flow Photoreactor Enabled by High-Power LEDs

A cost-effective, high-throughput plug-flow photoreactor capable of producing kilogram quantities of material per day has been developed using high-power LEDs to maximise photon flux and minimise reactor footprint. Systematic evaluation of tube diameter ensured optimal light absorption without increasing photocatalyst levels. Reaction optimisation through DoE enabled high yields and conversion, with the reactor achieving up to 12 kg of material per day at 90% conversion during extended continuous operation.

CSTR Cascade for Solid-Containing Photochemical Reactions

A new solid-handling platform for heterogeneous photoredox chemistry is presented, integrating a solid-feeding strategy with a continuous stirred-tank reactor cascade. Hydrodynamic studies were conducted for both liquid and solid phases to characterise residence-time behaviour. The system was successfully applied to silyl radical-mediated metallaphotoredox cross-electrophile coupling, enabling stable gram-scale synthesis over 13 hours of continuous operation.

Photons as a 21st-Century Reagent

This perspective outlines how fundamental photochemical principles such as photon stoichiometry, intensity and energy balance guide the translation of photochemistry from laboratory to manufacturing scale. Emphasis is placed on understanding light as a quantifiable reagent essential for designing robust, scalable photochemical processes.

Teaching and Learning

Flow Chemistry in the Undergraduate Laboratory

Introducing flow chemistry early in academic training equips students with essential skills in continuous processing, microreactor operation and multi-step flow synthesis. Two undergraduate-level experiments—diazo dye synthesis and disulfide formation—demonstrate how low-risk, accessible flow-chemistry setups provide hands-on experience in both organic chemistry and chemical engineering. Students gain practical understanding of continuous reaction control, multiphase systems and modern processing methods highly valued across academia and industry.