Flow chemistry basics, use case I

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The transition from batch to continuous chemical synthesis offers significant opportunities for process intensification, improved safety, and streamlined scale-up. This presentation introduces a "toolbox approach" for systematically transferring batch reactions into continuous flow processes. The methodology is built on three key descriptors of a reacting system: Reaction kinetics and hazards (classified as Type A, B, or C reactions), reacting phases (single-phase and multiphase systems), and reaction network complexity (parallel and consecutive reactions).[1] By combining these criteria within a structured decision matrix, the approach enables the rational selection of the most appropriate continuous reactor module: Plate reactors, tubular/coil reactors, or continuous stirred tank reactor cascades (CSTRs) - and their optimal configuration.

The toolbox emphasizes the principle of using miniaturization only where it provides a clear benefits, rather than enforcing a fully micro-structured process design. Dimensionless analysis using Damköhler numbers is applied to guide reactor sizing and ensure consistency in performance during scale-up. The flexibility of this modular strategy is demonstrated through industrially relevant case studies. For example a highly exothermic lithiation reaction characterize through a flow calorimeter and a ring-closing metathesis where mixed-flow operation enables catalyst protection and enhanced yield.

Overall, the toolbox approach provides a practical, scalable framework for selecting "the right reactor at the right place," offering a robust pathway for integrating continuous flow technologies into chemical process development while preserving product quality, safety, and efficiency.

Table 1. The reaction/reactor matrix

Rates / Phases	Homogeneous	Liquid-Liquid	Gas-Liquid	Solid-Liquid
Type A	**Plate SZ**	N.A.	Plate LL	**CSTR TVF**
Type B	Plates SZ **Tubular SM** + **Coil**	Plates **LL** Coil with **Pulse-Flow**	Plates LL + Coil with **pressure**	CSTRs / **Packed Bed** Coil with Pulse-Flow **(HP)**
Type C	Tubular SM + Coil	Static mixers Coil with **Pulse-Flow**	Static mixers + Coil with **pressure**	CSTRs Coil with Pulse-Flow **(HP)**

[1] Plouffe, P., Macchi, A. Roberge, D.M., *Org. Process Res. Dev.* **2014**, 18, 1286−1294.
[2] Doyle, B.J., Elsner, P., Gutmann, B., Hannaerts, O., Aellig, C., Macchi, A., Roberge, D.M., *Org. Process Res. Dev.* **2020**, 24, 2169−2182.