Advancing Chemical Development through Process Intensification, Automation, and Machine Learning.

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Process intensification via continuous operation combined with automated optimization and screening techniques offer opportunities for faster development and more efficient manufacture of diverse chemical products. This presentation starts with advances in process intensification and green chemistry achieved through micro-reaction technology and continuous multistep synthesis (flow chemistry). Case studies include individual intensified reaction units as well as on-demand synthesis of common pharmaceuticals in a plug-and-play, manually reconfigurable, refrigerator-sized manufacturing platform. Next, advances in automated screening and optimization of chemical reactions are highlighted as methods to accelerate translation of laboratory discoveries to manufacturing. Examples include optimization of thermal- and photo-chemical reactions in 15 microliter droplets with respect to continuous process conditions (temperature, time, concentrations…) and discrete process choices (catalysts, solvents, bases …). Finally, machine learning of chemical information is applied to computer aided chemical synthesis - the planning of reaction paths to a given molecular target from purchasable starting materials. With expert user input, the synthesis plans are converted into recipes that are executed by an automated modular continuous flow platform configured by a robotic arm, which sets up the required unit operations. Examples of automatic continuous syntheses of pharmaceutical compounds and libraries illustrate the promise of this combined approach of machine learning, reaction engineering, and robotics.