Research Highlights

Highlights from the Flow Chemistry Literature 2014 (Part 1)

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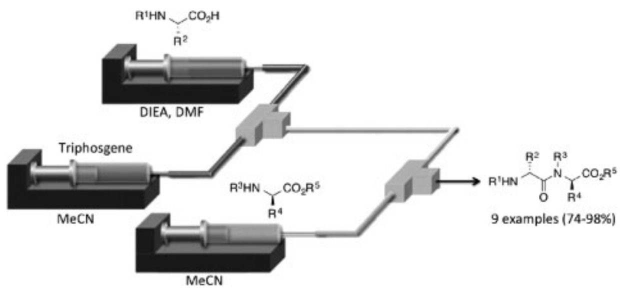
In this section of the journal, the continuous-flow chemistry literature of the preceding months is presented. Included are articles published in the period October–December 2013 and January–March 2014. Some key examples are highlighted in the form of graphical abstracts. The remaining publications in the field are then listed ordered by journal name, with review articles grouped at the end.

01/2014

Efficient Amide Bond Formation through a Rapid and Strong Activation of Carboxylic Acids in a Microflow Reactor
S. Fuse,* Y. Mifune, T. Takahashi

Angew. Chem., Int. Ed. **2014**, *53*, 851–855 *DOI: 10.1002/anie.201307987*

An efficient continuous-flow approach towards the synthesis of dipeptides has been accomplished. Various amino acids can be rapidly converted into highly reactive species via reaction with inexpensive triphosgene. Following in situ reaction with a second amino acid affords the corresponding dipeptide (5 s total reaction time). High yields and low rates of epimerization (≤3 %) were achieved. The reaction proceeds at room temperature, and the side products are only CO_2 and an HCl salt of the used organic base.

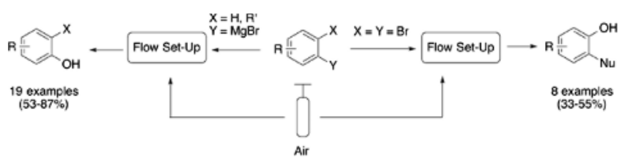


02/2014

Continuous-Flow Synthesis of Functionalized Phenols by Aerobic Oxidation of Grignard Reagents
Z. He, T. F. Jamison*

Angew. Chem., Int. Ed. **2014**, *53*, 3353–3357 *DOI:10.1002/anie.201310572*

An environmentally friendly and cost-effective phenol synthesis through a direct oxidation of aryl Grignard reagents using compressed air in continuous gas–liquid segmented flow system has been carried out. A large variety of substituents are tolereated, including oxidation-sensitive functionalities such as alkenes, amines, and thioethers. Integration of the aerobic oxidation process with a benzyne-mediated in-line generation of arylmagnesium intermediates allows a facile three-step, one-flow process, delivering 2-functionalized phenols in a modular fashion.



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DOI: 10.1556/JFC-D-14-00010

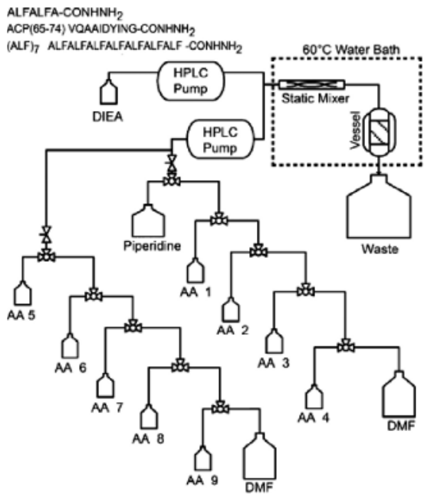
03/2014

Rapid Flow-Based Peptide Synthesis

M. D. Simon, P. L. Heider, A. Adamo, A. A. Vinogradov, S. K. Mong, X. Li, T. Berger, R. L. Policarpo, C. Zhang, Y. Zou, X. Liao, A. M. Spokoyny, K. F. Jensen, B. L. Pentelute*

ChemBioChem **2014**, *15*, 713–720 *DOI:10.1002/cbic.201300796*

A rapid flow-based solid-phase peptide synthesis methodology that enables the incorporation of an amino acid residue every 1.8 min (automatic control) or every 3 min (manual control) is described. The fast processing is achieved by passing a stream of reagent through a heat exchanger into a low volume, low backpressure reaction vessel. Thus, continuous delivery of heated solvents and reagents to the solid support at high flow rate is made possible. An ultraviolet (UV) detector is used for continuous monitoring of the process. A broad range of small peptides as well as a small protein have been prepared, and the obtained materials were of comparable quality to those from traditional batch methods.



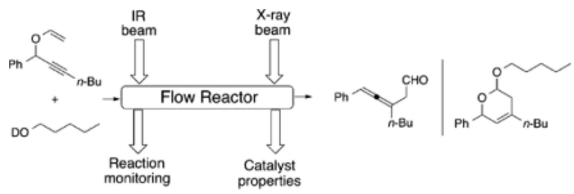
04/2014

In Situ IR and X-ray High Spatial-Resolution Microspectroscopy Measurements of Multistep Organic Transformation in Flow Microreactor Catalyzed by Au Nanoclusters

E. Gross, X.-Z. Shu, S. Alayoglu, H. A. Bechtel, M. C. Martin, F. D. Toste,* G. A. Somorjai*

J. Am. Chem. Soc. **2014**, *136,* 3624–3629 *DOI:10.1021/ja412740p*

A continuous-flow reactor with Au-nanocluster supported on mesoporous SiO_2 and in-line infrared (IR) and X-ray analysis were employed for the spectral mapping of a multistep catalytic formation of pyrans. High catalytic conversions and tunable product selectivity were achieved. IR microspectroscopy was used in the monitoring of the reaction progress while an X-ray absorption spectroscopy scan along the flow reactor allowed the correlation of the observed locally enhanced catalytic activity to the areas with higher concentrations of Au(III)-species.



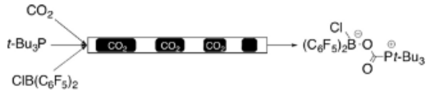
05/2014

Microfluidic Studies of CO_2 Sequestration by Frustrated Lewis Pairs

D. Voicu, M. Abolhasani, R. Choueiri, G. Lestari, C. Seiler, G. Menard, J. Greener, A. Guenther, D. W. Stephan, E. Kumacheva*

J. Am. Chem. Soc. **2014**, *136*, 3875–3880 *DOI:10.1021/ja411601a*

A microfluidic approach for reversible CO_2-capture has been developed. The flow set-up allows the determination of equilibrium reaction constants at different temperatures, the enthalpy, the entropy, and the Gibbs energy, as well as the enhancement factor in the reaction of CO_2 with frustrated Lewis pair systems (FLPs). This aims to help the optimization of FLPs for the efficient CO_2-capture and is otherwise not easily achievable.

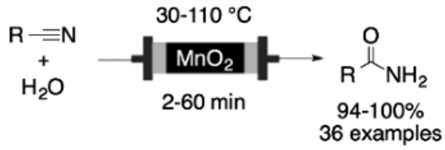


06/2014

Mild and Selective Heterogeneous Catalytic Hydration of Nitriles to Amides by Flowing through Manganese Dioxide
C. Battilocchio, J. M. Hawkins, S. V. Ley*

Org. Lett. **2014**, *14*, 1060–1063 *DOI:10.1021/ol403591c*

A sustainable flow chemistry process for the synthesis of amides via the hydration of nitriles, whereby an aqueous solution of the nitrile and a cosolvent is passed through a prepacked column containing commercial MnO_2, has been developed. The product can be isolated by simple concentration of the output stream without the need of any further workup. It is a rapid, robust, and scalable (molar quantities) protocol that has been applied to a broad range of heteroaromatic, aromatic, and aliphatic nitriles (36), showing a high level of chemical tolerance to a broad spectrum of functional groups, e.g., esters, aldehydes, Michael acceptors, and benzylic alcohols.



Further Flow Chemistry Publications:

2013

"Heating under high-frequency inductive conditions: application to the continuous synthesis of the neurolepticum olanzapine (Zyprexa)"
J. Hartwig, S. Ceylan, L. Kupracz, L. Coutable, A. Kirschning*
Angewandte Chemie International Edition **2013**, *52*, 9813–9817

"Flow synthesis and biological studies of an analgesic adamantine derivative that inhibits P2X7-evoked glutamate release"
C. Battilocchio, L. Guetzoyan, C. Cervetto, L. D. C. Mannelli, D. Frattaroli, I. R. Baxendale G. Maura, A. Rossi, L. Sautebin, M. Biava, C. Ghelardini, M. Marcoli, S. V. Ley*
ACS Medicinal Chemistry Letters **2013**, *4*, 704–709

"A continuous flow solution to achieving efficient aerobic anti-Markovnikov Wacker oxidation"
S. L. Bourne, S. V. Ley*
Advanced Synthesis & Catalysis **2013**, *355*, 1905–1910

"Copper(I)/N-heterocyclic carbene (NHC)-catalyzed addition of terminal alkynes to trifluoromethyl ketones for use in continuous reactors"
C. A. Correia, D. T. McQuade,* P. H. Seeberger
Advanced Synthesis & Catalysis **2013**, *355*, 3517–3521

"Continuous-flow Heck synthesis of 4-methoxybiphenyl and methyl 4-methoxycinnamate in supercritical carbon dioxide expanded solvent solutions"
P. L. Lau, R. W. K. Allen, P. Styring*
Beilstein Journal of Organic Chemistry **2013**, *9*, 2886–2897

"A microfluidic system for the continuous recycling of unmodified homogeneous palladium catalysts through liquid/liquid phase separation"
P. Li,* J. S. Moore, K. F. Jensen*
ChemCatChem **2013**, *5*, 1729–1733

"On-chip catalytic microreactors for modern catalysis research"
B.-B. Xu, Y.-L. Zhang,* S. Wei, H. Ding, H.-B. Sun*
ChemCatChem **2013**, *5*, 2091–2099

"Multistep continuous-flow synthesis in medicinal chemistry: discovery and preliminary structure–activity relationships of CCR8 ligands"
T. P. Petersen, S. Mirsharghi, P. C. Rummel, S. Thiele, M. M. Rosenkilde, A. Ritzen,* T. Ulven*
Chemistry European Journal **2013**, *19*, 9343–9350

"Two-phase enzymatic reaction using process intensification techniques"
S. Elgue,* A. Conte,* A. Marty, J.-S. Condoret
Chemistry Today **2013**, *31*(6), 43–47

"Efficient terpene synthase catalysis by extraction in flow"
O. Cascon, G. Richter, R. K. Allemann,* T. Wirth*
ChemPlusChem **2013**, *78*, 1334–1337

"Hydrogen production through aqueous-phase reforming of ethylene glycol in a wash coated microchannel"
M. F. N. D'Angelo, V. Ordomsky, V. Paunovic, J. van der Schaaf, J. C. Schouten, T. A. Nijhuis*
ChemSusChem **2013**, *6*, 1708–1716

"Asymmetric anti-Mannich reactions in continuous flow"
R. Martin-Rapun,* S. Sayaleroa, M. A. Pericas*
Green Chemistry **2013**, *15*, 3295–3301

"Microwave heating and conventionally-heated continuous-flow processing as tools for performing cleaner palladium-catalyzed decarboxylative couplings using oxygen as the oxidant — a proof of principle study"
D. M. Rudzinski, N. E. Leadbeater*
Green Processing & Synthesis **2013**, *2*, 323–328

"Integrated lipase-catalyzed isoamyl acetate synthesis in a miniaturized system with enzyme and ionic liquid recycle"
U. Novak, P. Znidarsic-Plazl*
Green Processing & Synthesis **2013**, *2*, 561–568

"NADH oxidation in a microreactor catalysed by ADH immobilised on γ-Fe_2O_3 nanoparticles"
A. Salic, K. Pindric, G. H. Podrepsek, M. Leitgeb,* B. Zelic*
Green Processing & Synthesis **2013**, *2*, 569–578

"A comparative study of ultrasound-, microwave-, and microreactor-assisted imidazolium-based ionic liquid synthesis"
M. C. Bubalo, I. Sabotin, I. Rados, J. Valentincic, T. Bosiljkov, M. Brncic, P. Znidarsic-Plazl*
Green Processing & Synthesis **2013**, *2*, 579–590

"Improving energy efficiency of process of direct adipic acid synthesis in flow using pinch analysis"
I. Vural-Gürsel, Q. Wang, T. Noël, V. Hessel,* J. T. Tinge
Industrial & Engineering Chemistry Research **2013**, *52*, 7827–7835

"ADH based NAD^+ regeneration in a microreactor"
A. Salic, M. Ivankovic, E. Ferk, B. Zelic*
Journal of Chemical Technology & Biotechnology **2013**, *88*, 1721–1729

"Progress in computational microfluidics using TransAT"
D. Lakehal, C. Narayanan, D. Caviezel, J. von Rickenbach, S. Reboux
Microfluidics and Nanofluidics **2013**, *15*, 415–429

"Phase transfer catalyzed esterification: modeling and experimental studies in a microreactor under parallel flow conditions"
E. Sinkovec, A. Pohar, M. Krajnc*
Microfluidics and Nanofluidics **2013**, *14*, 489–498

"Application of continuous flow micromixing reactor technology for synthesis of benzimidazole drugs"
G. S. Reddy, N. S. Reddy, K. Manudhane, M. V. R. Krishna, K. J. S. Ramachandra, S. Gangula*
Organic Process Research & Development **2013**, *17*, 1272–1276

"Siloxane photopolymer to replace polydimethylsiloxane in microfluidic devices for polymerase chain reaction"
A. Vitale,* M. Quaglio, S. Turri, M. Cocuzza, R. Bongiovani
Polymers Advanced Technologies **2013**, *24*, 1068–1074

Reviews:

"Materials for Microfluidic Chip Fabrication"
K. Ren, J. Zhou, H. Wu
Accounts of Chemical Research **2013**, *46*, 2396–2406

"Asymmetric carbon–carbon bond formation under continuous-flow conditions with chiral heterogeneous catalysts"
T. Tsubogo, T. Ishiwata, S. Kobayashi*
Angewandte Chemie International Edition **2013**, *52*, 6590–6604

"Applications, benefits and challenges of flow chemistry"
A. Mitic, S. Heintz, R. H. Ringborg, V. Bodla, J. M. Woodley, K. V. Gernaey*
Chemistry Today **2013**, *31*, 4–8

"Flow chemistry approaches directed at improving chemical synthesis"
I. R. Baxendale,* L. Brocken, C. J. Mallia
Green Processing & Synthesis **2013**, *2*, 211–230

"Multiphase biotransformations in microstructured reactors: opportunities for biocatalytic process intensification and smart flow processing"
J. M. Bolivar, B. Nidetzky*
Green Processing & Synthesis **2013**, *2*, 541–559

"Flow chemistry for designing sustainable chemical synthesis"
B. R. Vaddula, M. A. Gonzalez
Chemistry Today **2013**, *31*, 16–20

"Continuous processes — sustainable manufacturing"
J. Schrickel
Chemistry Today **2013**, *31*, 22–25

"Smart enzyme immobilization in microstructured reactors"
J. M. Bolivar, B. Nidetzky
Chemistry Today **2013**, *31*(3), 50–54

"Accelerating photoredox catalysis in continuous microflow"
T. Noel
Chemistry Today **2013**, *31*(3), 10–14 (Monographic Supplement Series)

2014

""Batch" kinetics in flow: online IR analysis and continuous control"
J. S. Moore, K. F. Jensen*
Angewandte Chemie International Edition **2014**, *53*, 470–473

"Combining on-chip synthesis of a focused combinatorial library with computational target prediction reveals imidazopyridine GPSR ligands"
M. Reutlinger, T. Rodrigues, P. Schneider, G. Schneider*
Angewandte Chemie International Edition **2014**, *53*, 582–585

"Seamless integration of dose–response screening and flow chemistry: efficient generation of structure–activity relationship data of β-secretase (BACE1) inhibitors"
M. Werner,* C. Kuratli, R. E. Martin,* R. Hochstrasser, D. Wechsler, T. Enderle, A. I. Alanine, H. Vogel
Angewandte Chemie International Edition **2014**, *53*, 1704–1708

"High-rate continuous synthesis of nanocrystalline perovskites and metal oxides in a colliding vapor stream of microdroplets"
T. Ould-Ely, L. Kaplan-Reinig, D. E. Morse *
Advanced Functional Materials **2014**, *24*, 1275–1282

"One-step two-dimensional microfluidics-based synthesis of three-dimensional particles"
N. Hakimi, S. S. H. Tsai, C.-H. Cheng, D. K. Hwang*
Advanced Functional Materials **2014**, *24*, 1393–1398

"Synthesis of 3-arylated 3,4-dihydrocoumarins: combining continuous flow hydrogenation with laccase-catalysed oxidation"
S. Suljic, J. Pietruszka,*
Advanced Synthesis & Catalysis **2014**, *356*, 1007–1020

"Preparation of reusable bioreactors using reversible immobilization of enzyme on monolithic porous polymer support with attached gold nanoparticles"
Y. Lv, Z. Lin, T. Tan, F. Svec*
Biotechnology & Bioengineering **2014**, *111*, 50–58

"Integration of enabling methods for the automated flow preparation of piperazine-2-carboxamide"
R. J. Ingham, C. Battilocchio, J. M. Hawkins, S. V. Ley*
Beilstein Journal of Organic Chemistry **2014**, *10*, 641–652

"Robust and reusable supported palladium catalysts for cross-coupling reactions in flow"
W. R. Reynolds, P. Plucinski, C. G. Frost*
Catalysis Science & Technology **2014**, *4*, 948–954

"Heterogenized gold(I)–carbene as a single-site catalyst in continuous flow"
C. Lothschtz, J. Szlachetko, J. A. van Bokhoven*
ChemCatChem **2014**, *6*, 443–448

"Reusable supported ruthenium catalysts for the alkylation of amines by using primary alcohols"
S. P. Shan, T. T. Dang, A. M. Seayad, B. Ramalingam*
ChemCatChem **2014**, *6*, 808–814

"Electrochemical conversion of dichloroacetic acid to chloroacetic acid in conventional cell and in two microfluidic reactors"
O. Scialdone,*A. Galia, S. Sabatino, G. M. Vaiana, D. Agro, A. Busacca, C. Amatore
ChemElectroChem **2014**, *1*, 116–124

"Investigation of a lithium–halogen exchange flow process for the preparation of boronates by using a cryo-flow reactor"
J. A. Newby, L. Huck, D. W. Blaylock, P. M. Witt, S. V. Ley, D. L. Browne*
Chemistry A European Journal **2014**, *30*, 263–271

"Enantioselective continuous-flow production of 3-indolylmethanamines mediated by an immobilized phosphoric acid catalyst"
L. Osorio-Planes, C. Rodriguez-Escrich, M. A. Pericas*
Chemistry A European Journal **2014**, *30*, 2367–2372

"Biocompatible macro-initiators controlling radical retention in microfluidic on-chip photopolymerization of water-in-oil emulsions"
Y. Ma, J. Thiele, L. Abdelmohsen, J. Xu, W. T. S. Huck*
Chemical Communications **2014**, *50*, 112–114

"Selective monomethylation of primary amines with simple electrophiles"
T. Lebleu, X. Ma, J. Maddaluno, J. Legros*
Chemical Communications **2014**, *50*, 1836–1838

"Controlling size, crystallinity, and electrochemical performance of $Li_4Ti_5O_{12}$ nanocrystals"
Y. Shen, J. R. Eltzholtz, B. B. Iversen*
Chemistry of Materials **2014**, *25*, 5023–5030

"Mechanism-guided design of flow systems for multicomponent reactions: conversion of CO_2 and olefins to cyclic carbonates"
J. Wu, J. A. Kozak, F. Simeon, T. A. Hatton,* T. F. Jamison*
Chemical Science **2014**, *5*, 1227–1231

"Catalytic transfer hydrogenation/hydrogenolysis for reductive upgrading of furfural and 5-(hydroxymethyl)furfural"
D. Scholz, C. Aellig, I. Hermans*
ChemSusChem **2014**, *7*, 268–275

"Tube-in-tube reactor as a useful tool for homo- and heterogeneous olefin metathesis under continuous flow mode"
K. Skowerski,* S. J. Czarnocki, P. Knapkiewicz
ChemSusChem **2014**, *7*, 536–542

"Microfluidic platform for continuous flow synthesis of triangular gold nanoplates"
D. V. R. Kumar, A. A. Kulkarni,* B. L. V. Prasad*
Colloids and Surfaces A: Physicochemical and Engineering Aspects **2014**, *443*, 149–155

"Glucose-6-phosphate dehydrogenase encapsulated in silica-based hydrogels for operation in a microreactor"
S. Cumana,* I. Ardao, A.-P. Zeng, I. Smirnova
Engineering in Life Sciences **2014**, *14*, 170–179

"A continuous process for glyoxal valorisation using tailored Lewis-acid zeolite catalysts"
P. Y. Dapsens, C. Mondelli,* B. T. Kusema, R. Verel, J. Perez-Ramirez*
Green Chemistry **2014**, *16*, 1176–1186

"Supported ionic liquid-like phases as organocatalysts for the solvent-free cyanosilylation of carbonyl compounds: from batch to continuous flow process"
S. Martin, R. Porcar, E. Peris, M. I. Burguete, E. Garcia-Verdugo,* S. V. Luis*
Green Chemistry **2014**, *16*, 1639–1647

"Olefin autoxidation in flow"
U. Neuenschwander, K. F. Jensen*
Industrial & Engineering Chemistry Research **2014**, *53*, 601–608

"Photocatalytic hydrodefluorination: facile access to partially fluorinated aromatics"
S. M. Senaweera, A. Singh, J. D. Weaver*
Journal of the American Chemical Society **2014**, *136*, 3002–3005

"Continuous enzymatic carboligation of benzaldehyde and acetaldehyde in an enzyme ultrafiltration membrane reactor and laminar flow microreactors"
D. Valingera,* A. V. Presecki, Z. Kurtanjek, M. Pohl, Z. F. Blazevic, D. Vasic-Racki
Journal of Molecular Catalysis B: Enzymatic **2014**, *102*, 132–137

"Decarboxylative trichloromethylation of aromatic aldehydes and its applications in continuous flow"
A. B. Jensen, A. T. Lindhardt*
Journal of Organic Chemistry **2014**, *79*, 1174–1183

"Continuous flow synthesis of α-halo ketones: essential building blocks of antiretroviral agents"
V. D. Pinho, B. Gutmann, L. S. M. Miranda, R. O. M. A. de Souza, C. O. Kappe*
Journal of Organic Chemistry **2014**, *79*, 1555–1562

"Comparison of flow and batch polymerization processes for production of vinyl ether terpolymers for use in the delivery of siRNA"
J. L. Nyrop, A. Soheili, R. Xiang, F. Meng, J. H. Waldman, X. Jia, R. G. Parmar, B. W. Thuronyi, J. M. Williams, L. Di Michele, M. Journet, B. J. Howell, B. Mao, I. W. Davies, S. L. Colletti, L. Sepp-Lorenzino, E. N. Guidry*
Journal of Polymer Science Part A: Polymer Chemistry **2014**, *52*, 1119–1129

"High throughput synthesis of uniform biocompatible polymerbeads with high quantum dot loading using microfluidic jet-mode breakup"
S.-K. Lee, J. Baek, K. F. Jensen*
Langmuir **2014**, *30*, 2216–2222

"Scaled-up production of plasmonic nanoparticles using microfluidics: from metal precursors to functionalized and sterilized nanoparticles"
L. Gomez, V. Sebastian,* S. Irusta, A. Ibarra, M. Arruebo, J. Santamaria*
Lab on a Chip **2014**, *14*, 325–332

"Whole ceramic-like microreactors from inorganic polymers for high temperature or/and high pressure chemical syntheses"
W. Ren, J. Perumal, J. Wang, H. Wang, S. Sharmac, D.-P. Kim*
Lab on a Chip **2014**, *14*, 779–786

"Continuous synthesis of zinc oxide nanoparticles in a microfluidic system for photovoltaic application"
H. W. Kang, J. Leem, S. Y. Yoon, H. J. Sung*
Nanoscale **2014**, *6*, 2840–2846

"Continuous flow α-trifluoromethylation of ketones by metal-free visible light photoredox catalysis"
D. Cantillo, O. de Frutos, J. A. Rincoon,* C. Mateos, C. O. Kappe*
Organic Letters **2014**, *16*, 896–899

"Continuous photochemical cleavage of linkers for solid-phase synthesis"
M. Hurevich, J. Kandasamy, B. M. Ponnappa, M. Collot, D. Kopetzki, D. T. McQuade, P. H. Seeberger*
Organic Letters **2014**, *16*, 1794–1797

"Development of a multi-step synthesis and workup sequence for an integrated, continuous manufacturing process of a pharmaceutical"
P. L. Heider, S. C. Born, S. Basak, B. Benyahia, R. Lakerveld, H. Zhang, R. Hogan, L. Buchbinder, A. Wolfe, S. Mascia, J. M. B. Evans, T. F. Jamison, K. F. Jensen*
Organic Process Research and Development **2014**, *18*, 402–409

"Photo-induced copper-mediated polymerization of methyl acrylate in continuous flow reactors"
B. Wenn, M. Conradi, A. D. Carreiras, D. M. Haddleton, T. Junkers*
Polymer Chemistry **2014**, *5*, 3053–3060

"Chemoselective flow hydrogenation approaches to isoindole-7-carboxylic acids and 7-oxa- bicyclio[2.2.1]heptanes"
L. Hizartzidis, M. Tarleton, C. P. Gordon, A. McCluskey*
RSC Advances **2014**, *4*, 9709–9722

"Flash carboxylation: fast lithiation–carboxylation sequence at room temperature in continuous flow"
B. Pieber, T. Glasnov, C. O. Kappe*
RSC Advances **2014**, *4*, 13430–13433

"Two-step continuous-flow synthesis of $CuInSe_2$ nanoparticles in a solar microreactor"
P. B. Kreider, K.-J. Kim, C.-H. Chang*
RSC Advances **2014**, *4*, 13827–13830

"Nonenzymatic sugar production from biomass using biomass-derived γ-valerolactone"
J. S. Luterbacher, J. M. Rand, D. M. Alonso, J. Han, J. T. Youngquist, C. T. Maravelias, B. F. Pfleger, J. A. Dumesic*
Science **2014**, *343*, 277–280

"Safe generation and direct use of diazoesters in flow chemistry"
S. T. R. Müller, D. Smith, P. Hellier, T. Wirth*
Synlett **2014**, *25*, 871–875

Reviews:

"Continuous flow nitration in miniaturized devices"
A. A. Kulkarni
Beilstein Journal of Organic Chemistry **2014**, *10*, 405–424

"Biocatalytic process development using microfluidic miniaturized systems"
U. Krühne, S. Heintz, R. Ringborg, I. P. Rosinha, P. Tufvesson, K. V. Gernaey, J. M. Woodley*
Green Processing & Synthesis **2014**, *3*, 23–31

"Microfluidic platforms: a mainstream technology for the preparation of crystals"
J. Puigmarti-Luis*
Chemical Society Reviews **2014**, *43*, 2253–2271