

Conference Report

The 56th Bürgenstock Conference

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The 56th edition of the Bürgenstock conference was held on May 7–11, 2023, in Brunnen, an idyllic Swiss village of canton Schwyz, hosting attendees in the Seehotel Waldstätterhof with a panoramic view of the lake Lucerne and the Swiss Alps (Fig. 1). When asked about the Bürgenstock conference, many attendees would describe it as one of the most esteemed and unique meetings in the field. The Swiss Chemical Society (SCS) Conference on Stereochemistry, better known as the Bürgenstock conference, has a longstanding tradition dating back to 1965, welcoming international academic and industrial experts from diverse fields of chemistry. This invitation-only event has been praised for its unparalleled immersive setup featuring a panel of speakers at the pinnacle of their careers. The list of attendees traditionally remains a well-kept secret until the event's opening, adding an element of anticipation and excitement to the occasion. Delivering a plenary talk at this event is a once-in-a-lifetime opportunity, as presenting more than once is usually reserved for those who have transitioned across different fields. The level of expertise within a relatively small number of attendees further contributes to a unique atmosphere and the level of discussions during the Q&A session following each talk. The conference also provides ample formal and informal networking opportunities, augmented by the fact that the conference hotel serves as the venue.

The organization of this year's Bürgenstock Conference was led by President Alois Fürstner from the Max Planck Institute Mülheim an der Ruhr and Vice-President Erick Carreira from ETH Zurich. The Guest of Honor was Andreas Pfaltz from the University of Basel, and the Organizing Committee involved Fabrice Gallou (Novartis), Cristina Nevado (University of Zurich), Francesca Paradisi (University of Bern), Maud Reiter (Firmenich), Thomas Ward (University of Basel), and Jérôme Waser (EPFL) (Fig. 2). The organizing committee, along with assistants Pablo Díaz-Kruik (University of Bern), Mikus Puriš (EPFL), and Dongping Chen (University of Basel), contributed to the success of the event.



Fig. 1. Impression from the 56th Bürgenstock Conference in Brunnen, Switzerland. Photo credit: Jovana V. Milić.



Fig. 2. Organizing committee of the 56th Bürgenstock Conference in Brunnen, Switzerland. From left to right: Fabrice Gallou, Thomas Ward, Francesca Paradisi, Alois Fürstner, Cristina Nevado, Maud Reiter, and Jérôme Waser. Photo credit: Richard Smith (*Helv. Chim. Acta*).

One of the significant aspects of the conference is the Junior Scientist Participants (JSP) Program, made possible with the support of the Division of Fundamental Research of the Swiss Chemical Society and sponsors, including Thieme, *Science*, *Nature Synthesis*, *Helvetica Chimica Acta*, and Syngenta. Each year, 10–15 selected scientists in the early stages of their academic or industrial careers are awarded fellowships to attend the Bürgenstock conference. The JSP 2023 fellows (Fig. 3) were Athina Anastasaki (ETH Zurich), Clément Camp (CPE Lyon), Alicia Casitas (University of Marburg), Aurélien de la Torre (Institut de Chimie Moléculaire et des Matériaux d'Orsay), Adrian Gomez Suarez (University of Wuppertal), Max M. Hansmann (Technische Universität Dortmund), Quentin Lefebvre (Spirochem AG), Jovana V. Milić (University of Fribourg), Constanze N. Neumann (MPI Mülheim), Wade F. Petersen (University of Cape Town), Marc Reid (University of Strathclyde), Loïc Roch (Atinary Technologies Inc.), Ben Schumann (Imperial College London), Christopher J. Teskey (RWTH Aachen), Zachary Wickens (University of Wisconsin-Madison), Sidney M. Wilkerson-Hill (UNC Chapel Hill), and Cayetana Zarate (Janssen Pharmaceuticals).



Fig. 3. The JSP 2023 Fellows. Photo credit: Jeannette Meier Kamer (Maier & Kamer GmbH) and SCS.

The scientific program featured an engaging lineup of speakers over five days, encompassing a diverse range of topics and discussions that spanned various areas of chemistry and related disciplines, including organic synthesis, catalysis, main group and organometallic chemistry, biochemistry, process chemistry, material chemistry, spectroscopy, and theoretical chemistry.



Tanja Gaich

Following the registration and the welcome dinner, including an inspiring speech by President Fürstner, the first day opened with a lecture by **Tanja Gaich** (University of Konstanz). She discussed ‘The Total Synthesis of Cyclotaxanes – a Deconvolution Approach’ in a session chaired by Erick Carreira (ETH Zurich). Gaich provided a broader perspective on the taxoid family synthesis and prior efforts to access the taxane core^[1,2] beyond the biosynthetic route,^[3] introducing synthetic challenges and solutions toward a deconvolution strategy to access cyclotaxane scaffolds.



Ryan Gilmour

The second day began with a morning session, chaired by Eva Hevia (University of Bern), including **Ryan Gilmour** (University of Münster), who talked about ‘Illuminating Alkene Isomerisation: From Basic Principles to Application in Stereocontrolled Polyene Synthesis’. He provided a perspective on his research influenced by Swiss chemistry mentors and pioneers. Inspired by the biomimetic approaches^[4] and ratchet mechanisms,^[5] Gilmour introduced ‘directionality’ to olefin $E \rightarrow Z$ isomerization *via* selective energy transfer.^[6] He shared mechanistic insights^[7] and showcased the utility of this ‘contra-thermodynamic’ approach in the emulation of coumarin biosynthesis^[8] and the synthesis of conjugated vinyl organometallics,^[9–11] and polyenes,^[12,13] leaving a question of whether isomerization could reach ‘strategy-level status’.^[14]



SunSuke Chiba

The morning session continued with **SunSuke Chiba** (Nanyang Technological University) presenting on ‘Synthetic Chemistry with Main Group Metal Hydrides’. He outlined various synthetic approaches,^[15] with a special focus on the counter-ion metathesis with NaI for activating NaH as a hydride source.^[16] He exemplified the versatility of this system in several synthetic transformations, such as the hydride reduction of carboxamides and aliphatic amides^[16–18] and the hydro-functionalization of unsaturated bonds, among others.^[19] This opened the path for further reactivities of main group metal hydrides, including KH^[20] and organomagnesium reagents.^[21,22]



Rebecca Buller and Emilie Balskus

The afternoon sessions, chaired by Rebecca Buller (ZHAW School of Life Sciences and Facility Management, Wädenswil, Switzerland), shifted the focus from synthetic chemistry to chemical biology. The session commenced with **Emilie Balskus** (Harvard University) delving into ‘Deciphering the Human Microbiome with Chemistry’. She highlighted the influence of the microorganisms comprising the human gut microbiome, discussing the efforts to identify the link between chemical

processes carried out by the gut microbiome and diseases like colorectal cancer (CRC). Balskus described the characterization of the metabolic activity of colibactin, a genotoxin produced by gut microbes associated with CRC. Utilizing untargeted DNA ‘adductomics’ and chemical synthesis, her team identified that colibactin modifies DNA through an unusual electrophilic cyclopropane^[23] and elucidated the biosynthetic mechanism behind the activity.^[24] Finally, she revealed how colibactin production can impact the microbiome,^[25] offering a molecular perspective to gut microbial activities with potential application in the treatment and prevention of diseases.

The session was followed by selected ‘flash’ presentations, highlighting some of the research presented at the poster session, including those by JSP Fellows. **Rebecca Buller’s** presentation focused on algorithm-aided enzyme engineering; **Aurélien de la Torre** (Institut de Chimie Moléculaire et des Matériaux d’Orsay) walked us through the total synthesis of Lucidumone; **Jovana V. Milić** (Adolphe Merkle Institute, University of Fribourg) discussed the role of supramolecular engineering to control hybrid materials in photovoltaics; **Ben Schumann** (Imperial College London) talked about the development of biorthogonal precision tools; and **Nicole Goodwin** explained how drug-discovery is accelerated through automated end-to-end direct-to-biology (D2B) at GSK. After the series of presentations, attendees had the opportunity to exchange ideas at the poster session featuring a wide range of topics.



Petra Schwillie

The evening session featured **Petra Schwillie** (Max Planck Institute for Biochemistry) discussing ‘Minimal Cell Division by Design’. Following the question on what are the minimal requirements for a functional cell,^[26] Schwillie addressed functional models based on proteins with the aim to assemble protocell-mimicking vesicles. Considering that life requires creating and maintaining order, including self-organization through a constant flow of energy, she explored the approaches to engineer system division or replication.^[27] Her team further investigated a self-organizing system at the basis of cell division and modeled the mechanics of the process for a better understanding of the requirements for the division of the vesicles, such as contraction and the formation of ring-like structures.^[27–29] Schwillie and her team considered other mechanisms^[29,30] and she concluded that nature’s complexity is not a requirement for life, yet it ensures stability, enabling competition and evolution. She also hinted at the perspectives for further understanding cell design involving artificial intelligence approaches to complex functions.



Serena DeBeer

On the third day, the morning session was moderated by Don Hilvert (ETH Zurich) and started with **Serena DeBeer** (Max Planck Institute for Chemical Energy Conversion) sharing insights on ‘Making and Breaking Bonds: Spectroscopic Studies of Energy Converting Enzymes’. She emphasized the importance of interdisciplinarity and highlighted the role of X-ray spectroscopy in providing atomic-level insights, offering examples of its use in understanding the biological machinery for nitrogen activation of nitrogenases.^[31] For instance, she used X-ray emission spectroscopy (XES) to analyze the active site of FeMo cofactor^[32] and X-ray absorption spectroscopy (XAS) to determine the local electronic structure.^[33,34] Finally, combining XES and small angle X-ray scattering (SAXS) provided more insights into the enzyme structure, offering a comprehensive assessment across length scales,^[35–37] while spectroelectrochemical approaches^[38] complemented the analysis for metalloenzymes and biohybrids with altered function.



Joseph Moran

Joseph Moran (University of Strasbourg) followed with a talk on ‘A Metabolic Approach to the Origin of Life’. He considered life from the perspective of a dynamic steady-state in the efforts to decipher prebiotic chemistry at its origin.^[39] The dynamics triggering spontaneous order in living systems were assumed to be driven by external stimuli, with (photo)redox chemistry playing an important role. To address these questions on the origin of life, he focused on nonenzymatic reactions at the core of proto-metabolism,^[40] exploring the role of metals comprising enzymatic cofactors^[41,42] in early carbon-carbon bond formations^[43] and other metabolic transformations.^[44] Finally, he argued that these metabolic pathways predated genetic information and discussed the possible role of the environment in the process.

The afternoon traditionally allowed the participants to engage in activities outside of the scientific program. The rainy weather that accompanied the event throughout the week cleared up, allowing attendees to enjoy outdoor activities. From boat trips and funicular rides to hiking trails that catered to diverse preferences, everyone had the chance to explore breathtaking locations like Sisikon, Seelisberg, Rigi Mountain, and the Rütli meadow.



Tim Donohoe

The fourth day opened with a morning session chaired by Manuel Alcarazo (Georg August Universität Göttingen), where **Tim Donohoe** (University of Oxford) presented on ‘Hydrogen Borrowing Catalysis and Organic Synthesis’. He discussed the versatility of ‘hydrogen borrowing’ strategies, which expand the utility of commodity alcohols toward various transformations using readily available catalysts under mild conditions.^[45] The potential was showcased in methylation,^[46,47] alkylation with higher alcohols,^[48,49] annulation,^[50,51] reductive functionalization,^[52–55] and applications to total synthesis.



Sukbok Chang

Next, **Sukbok Chang** (Korea Advanced Institute of Science and Technology) discussed ‘C–H Amidation Reactions via Nitrenoid Transfer: Validation of Its Intermediacy’. He provided an overview of his research developments relying on C–H activation reactions towards the formation of inter- and intramolecular C–N bonds using Ir, Cu and Ni catalysis.^[56,57] Chang also revealed the possibility of relying on X-ray photocrystallography^[58] through light-induced structural changes to assess metal complexes, such as in photochemical acyl nitrenoid transfer reactions.



Margaret Faul

In the afternoon session chaired by Edouard Godineau (Syngenta), **Margaret Faul** (Amgen Inc.) shared insights on ‘Innovative Strategies in the Development of Novel Therapeutics’. She provided a deep dive into process development and continuous manufacturing, showcasing how increased molecular complexity and accelerated timelines drive innovation of advanced manufacturing technologies. Furthermore, she addressed the importance of strategic investment in automation and provided examples of the application of high-throughput and computational modeling to drive drug development and manufacturing.^[59–61] Finally, with a reminder of serendipity in scientific discovery, she left the audience with a saying that “imperfect action is often better than perfect inaction”.

Before the second poster session, attendees had the opportunity to enjoy five short presentations. **Alicia Casitas** (Philipps-Universität Marburg) explained how high valent iron alkynyl and cyanide complexes can be synthesized using hypervalent iodine(III) reagents; **Laurence Grimaud** (École Normale Supérieure, PSL University, Sorbonne Université) talked about the applicability of microkinetic models and machine learning yield prediction tools (NiCOLit) in nickel catalysis; and entrepreneur **Loïc Roch** (Atinary Technologies Inc., Lausanne) explained how Atinary makes experiment planning more accessible and leverages data at full potential through no-code machine learning optimization platforms. **Mario Waser** (Johannes Kepler University) showcased the use of Lewis bases as catalysts in the asymmetric synthesis of chiral oxygen-containing heterocycles using allenolates, while **Zachary Wickens** (University of Wisconsin-Madison) talked about selective synthesis using electrochemistry and photochemistry focusing on alkene functionalization.



Ryan Shenvi

The evening session featured **Ryan Shenvi** (Scripps University), who explored ‘Natural Product Synthesis Through the Lens of Informatics’. He shared a perspective on synthesis as navigation of chemical space, enabling analog synthesis and opening diverse routes toward new functions.^[62] While arguing that small changes in the chemical space (*e.g.*, *via* divergent synthesis) do not necessarily alter the function, he encouraged alternate connections to provide new opportunities for discovery through dynamic strategic bond analysis with representative examples in total synthesis.^[63–65]

The evening closed with a memorable concert by Duo Nebiolo-Marenco (Non-Solo Tango by Alessio Nebiolo, guitar and Nadio Marenco, accordion), an original duo quite distinct from

classical chamber ensembles. The concert reflected the musical taste of President Fürstner and was an excellent prelude to the following farewell get-together.



Didier Bourissou

On the final day, the morning session was moderated by former conference president Janine Cossy (Ecole Supérieure de Physique et Chimie Industrielles de la Ville de Paris). First, **Didier Bourissou** (Institut de Chimie de Toulouse) presented on ‘Gold, a Noble but Reactive Metal, and a Unique Catalyst’. He provided a tour de force on the synthesis of gold complexes and their application in Au(I)/Au(III) catalysis.^[66–68]

His talk commenced with the synthesis of Au(I) complexes with carefully designed ligands to investigate stoichiometric fundamental steps in cross-coupling, including oxidative addition to C(sp²)-halogen bonds. He then ventured into Au catalysis showing examples of C–H arylation, alkene functionalization, and C–N cross-coupling reactions. He closed with recent work on the reactivity of π -allyl Au(III) complexes.^[69]



Frank Neese

The final speaker of the conference was **Frank Neese** (Max Planck Institute for Chemical Energy Conversion), who shared insights on ‘Why it is Fun to be a Theoretician Working in Catalysis’. In his presentation, centered on the advancement of computational molecular spectroscopy methods, he aimed at understanding molecular properties and reaction mechanisms. He emphasized that “the best methods are created by people who want to solve a problem.”^[70–72] Illustrating the practicality of computational approaches, he highlighted the use of tools like ORCA in deciphering magnetic properties and gaining insights into reaction mechanisms by computing the electronic structures of potential intermediates.^[73]

The conference concluded with the announcement of the 57th Bürgenstock conference in 2025, which will be chaired by Erick Carreira (ETH Zurich). Moreover, Cristina Nevado stepped down from the organizing committee (Fig. 4, left), while Karl Gademann joined as a new member. The 2025 vice-president was introduced, José Luis Mascareñas from Santiago de Compostela

University in Spain. Throughout the conference, attendees had the opportunity to engage with distinguished speakers and participants across a broad range of disciplines, fostering scientific exchange, inspiring collaborations, and this report (Fig. 4, right).

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Notes

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- [1] C.-H. Huo, X.-H. Su, Y.-F. Wang, X.-P. Zhang, Q.-W. Shi, H. Kiyota, *Tetrahedron Lett.* **2007**, *48*, 2721, <https://doi.org/10.1016/j.tetlet.2007.02.063>.
- [2] L. Min, J.-C. Han, W. Zhang, C.-C. Gu, Y.-P. Zou, C.-C. Li, *Chem. Rev.* **2023**, *123*, 4934, <https://doi.org/10.1021/acs.chemrev.2c00763>.
- [3] F. Schneider, L. Pan, M. Ottenbruch, T. List, T. Gaich, *Acc. Chem. Res.* **2021**, *54*, 2347, <https://doi.org/10.1021/acs.accounts.0c00873>.
- [4] A. G. Walker, G. K. Radda, *Nature* **1967**, *215*, 1483, <https://doi.org/10.1038/2151483a0>.
- [5] S. Amano, M. Esposito, E. Kreidt, D. A. Leigh, E. Penocchio, B. M. W. Roberts, *J. Am. Chem. Soc.* **2022**, *144*, 20153, <https://doi.org/10.1021/jacs.2c08723>.
- [6] T. Nevesely, M. Wienhold, J. J. Molloy, R. Gilmour, *Chem. Rev.* **2022**, *122*, 2650, <https://doi.org/10.1021/acs.chemrev.1c00324>.
- [7] T. Nevesely, J. J. Molloy, C. McLaughlin, L. Brüß, C. G. Daniliuc, R. Gilmour, *Angew. Chem. Int. Ed.* **2022**, *61*, e202113600, <https://doi.org/10.1002/anie.202113600>.
- [8] J. B. Metternich, R. Gilmour, *J. Am. Chem. Soc.* **2016**, *138*, 1040, <https://doi.org/10.1021/jacs.5b12081>.
- [9] J. J. Molloy, J. B. Metternich, C. G. Daniliuc, A. J. B. Watson, R. Gilmour, *Angew. Chem. Int. Ed.* **2018**, *57*, 3168, <https://doi.org/10.1002/anie.201800286>.
- [10] T. Hostmann, T. Nevesely, R. Gilmour, *Chem. Sci.* **2021**, *12*, 10643, <https://doi.org/10.1039/D1SC02454J>.
- [11] K. Livingstone, M. Tenberge, F. Pape, C. G. Daniliuc, C. Jamieson, R. Gilmour, *Org. Lett.* **2019**, *21*, 9677, <https://doi.org/10.1021/acs.orglett.9b03842>.
- [12] J. J. Molloy, M. Schäfer, M. Wienhold, T. Morack, C. G. Daniliuc, R. Gilmour, *Science* **2020**, *369*, 302, <https://doi.org/10.1126/science.abb7235>.



Fig. 4. Left: Concluding remarks by the organizing committee of the Bürgenstock Conference 2023 highlighting the sponsors of the event. Right: Impression from the Bürgenstock Conference 2023 in Brunnen by the two JPS Fellows Jovana V. Milić (left) and Cayetana Zarate (right).

- [13] M. Wienhold, B. Kweon, C. McLaughlin, M. Schmitz, T. J. B. Zähringer, C. G. Daniliuc, C. Kerzig, R. Gilmour, *Angew. Chem. Int. Ed.* **2023**, *62*, e202304150, <https://doi.org/10.1002/anie.202304150>.
- [14] A. Fürstner, *J. Am. Chem. Soc.* **2021**, *143*, 15538, <https://doi.org/10.1021/jacs.1c08040>.
- [15] M. M. D. Roy, A. A. Omaña, A. S. S. Wilson, M. S. Hill, S. Aldridge, E. Rivard, *Chem. Rev.* **2021**, *121*, 12784, <https://doi.org/10.1021/acs.chemrev.1c00278>.
- [16] Y. Huang, G. H. Chan, S. Chiba, *Angew. Chem. Int. Ed.* **2017**, *129*, 6644, <https://doi.org/10.1002/ange.201702512>.
- [17] D. Y. Ong, C. Tejo, K. Xu, H. Hirao, S. Chiba, *Angew. Chem. Int. Ed.* **2017**, *56*, 1840, <https://doi.org/10.1002/anie.201611495>.
- [18] D. Y. Ong, D. Fan, D. J. Dixon, S. Chiba, *Angew. Chem. Int. Ed.* **2020**, *59*, 11903, <https://doi.org/10.1002/anie.202004272>.
- [19] J. H. Pang, A. Kaga, S. Chiba, *Chem. Commun.* **2018**, *54*, 10324, <https://doi.org/10.1039/C8CC05979A>.
- [20] J. H. Pang, B. Wang, K. Watanabe, R. Takita, S. Chiba, *Helv. Chim. Acta* **2021**, *104*, e2100120, <https://doi.org/10.1002/hlca.202100120>.
- [21] B. Wang, D. Y. Ong, Y. Li, J. H. Pang, K. Watanabe, R. Takita, S. Chiba, *Chem. Sci.* **2020**, *11*, 5267, <https://doi.org/10.1039/D0SC01773F>.
- [22] Y. Li, J. Chen, J. J. W. Ng, S. Chiba, *Angew. Chem. Int. Ed.* **2023**, *62*, e202217735, <https://doi.org/10.1002/anie.202217735>.
- [23] M. R. Wilson, Y. Jiang, P. W. Villalta, A. Stornetta, P. D. Boudreau, A. Carrá, C. A. Brennan, E. Chun, L. Ngo, L. D. Samson, B. P. Engelward, W. S. Garrett, S. Balbo, E. P. Balskus, *Science* **2019**, *363*, eaar7785, <https://doi.org/10.1126/science.aar7785>.
- [24] Y. Jiang, A. Stornetta, P. W. Villalta, M. R. Wilson, P. D. Boudreau, L. Zha, S. Balbo, E. P. Balskus, *J. Am. Chem. Soc.* **2019**, *141*, 11489, <https://doi.org/10.1021/jacs.9b02453>.
- [25] J. E. Silpe, J. W. H. Wong, S. V. Owen, M. Baym, E. P. Balskus, *Nature* **2022**, *603*, 315, <https://doi.org/10.1038/s41586-022-04444-3>.
- [26] P. Schwille, *Angew. Chem. Int. Ed.* **2017**, *56*, 10998, <https://doi.org/10.1002/anie.201700665>.
- [27] M. Loose, E. Fischer-Friedrich, J. Ries, K. Kruse, P. Schwille, *Science* **2008**, *320*, 789, <https://doi.org/10.1126/science.1154413>.
- [28] T. Litschel, C. F. Kelley, D. Holz, M. Adeli Koudehi, S. K. Vogel, L. Burbaum, N. Mizuno, D. Vavylonis, P. Schwille, *Nat. Commun.* **2021**, *12*, 2254, <https://doi.org/10.1038/s41467-021-22422-7>.
- [29] S. Kohyama, A. Merino-Salomón, P. Schwille, *Nat. Commun.* **2022**, *13*, 6098, <https://doi.org/10.1038/s41467-022-33679-x>.
- [30] D. A. Ramirez-Diaz, D. A. García-Soriano, A. Raso, J. Mücksch, M. Feingold, G. Rivas, P. Schwille, *PLoS Biol.* **2018**, *16*, e2004845, <https://doi.org/10.1371/journal.pbio.2004845>.
- [31] C. Van Stappen, L. Decamps, G. E. I. Cutsail, R. Björnsson, J. T. Henthorn, J. A. Birrell, S. DeBeer, *Chem. Rev.* **2020**, *120*, 5005, <https://doi.org/10.1021/acs.chemrev.9b00650>.
- [32] J. K. Kowalska, J. T. Henthorn, C. Van Stappen, C. Trncik, O. Einsle, D. Keavney, S. DeBeer, *Angew. Chem. Int. Ed.* **2019**, *58*, 9292, <https://doi.org/10.1002/anie.201907043>.
- [33] T. Spatzal, K. A. Perez, J. B. Howard, D. C. Rees, *eLife* **2015**, *4*, e11620, <https://doi.org/10.7554/eLife.11620>.
- [34] G. E. I. Cutsail, R. Banerjee, A. Zhou, L. Jr. Que, J. D. Lipscomb, S. DeBeer, *J. Am. Chem. Soc.* **2018**, *140*, 16807, <https://doi.org/10.1021/jacs.8b10313>.
- [35] C. V. Stappen, A. T. Thorhallsson, L. Decamps, R. Björnsson, S. DeBeer, *Chem. Sci.* **2019**, *10*, 9807, <https://doi.org/10.1039/C9SC02187F>.
- [36] R. G. Castillo, J. T. Henthorn, J. McGale, D. Maganas, S. DeBeer, *Angew. Chem. Int. Ed.* **2020**, *59*, 12965, <https://doi.org/10.1002/anie.202003621>.
- [37] Z. Mathe, O. M. Stepanic, S. Peredkov, S. DeBeer, *Chem. Sci.* **2021**, *12*, 7888, <https://doi.org/10.1039/D1SC01266E>.
- [38] C. V. Stappen, B. Benediktsson, A. Rana, A. Chumakov, Y. Yoda, D. Bessas, L. Decamps, R. Björnsson, S. DeBeer, *Faraday Discuss.* **2023**, *243*, 253, <https://doi.org/10.1039/D2FD00174H>.
- [39] K. Ruiz-Mirazo, C. Briones, A. de la Escosura, *Chem. Rev.* **2014**, *114*, 285, <https://doi.org/10.1021/cr2004844>.
- [40] K. B. Muchowska, S. J. Varma, J. Moran, *Chem. Rev.* **2020**, *120*, 7708, <https://doi.org/10.1021/acs.chemrev.0c00191>.
- [41] K. B. Muchowska, S. J. Varma, E. Chevallot-Beroux, L. Le-thuillier-Karl, G. Li, J. Moran, *Nat. Ecol. Evol.* **2017**, *1*, 1716, <https://doi.org/10.1038/s41559-017-0311-7>.
- [42] S. A. Rauscher, J. Moran, *Angew. Chem. Int. Ed.* **2022**, *61*, e202212932, <https://doi.org/10.1002/anie.202212932>.
- [43] K. B. Muchowska, S. J. Varma, J. Moran, *Nature* **2019**, *569*, 104, <https://doi.org/10.1038/s41586-019-1151-1>.
- [44] R. J. Mayer, H. Kaur, S. A. Rauscher, J. Moran, *J. Am. Chem. Soc.* **2021**, *143*, 19099, <https://doi.org/10.1021/jacs.1c08535>.
- [45] B. G. Reed-Berendt, D. E. Latham, M. B. Dambatta, L. C. Morrill, *ACS Cent. Sci.* **2021**, *7*, 570, <https://doi.org/10.1021/acscentsci.1c00125>.
- [46] L. K. M. Chan, D. L. Poole, D. Shen, M. P. Healy, T. J. Donohoe, *Angew. Chem. Int. Ed.* **2014**, *53*, 761, <https://doi.org/10.1002/anie.201307950>.
- [47] D. Shen, D. L. Poole, C. C. Shotton, A. F. Kornahrens, M. P. Healy, T. J. Donohoe, *Angew. Chem. Int. Ed.* **2015**, *54*, 1642, <https://doi.org/10.1002/anie.201410391>.
- [48] J. R. Frost, C. B. Cheong, W. M. Akhtar, D. F. J. Caputo, N. G. Stevenson, T. J. Donohoe, *J. Am. Chem. Soc.* **2015**, *137*, 15664, <https://doi.org/10.1021/jacs.5b11196>.
- [49] W. M. Akhtar, C. B. Cheong, J. R. Frost, K. E. Christensen, N. G. Stevenson, T. J. Donohoe, *J. Am. Chem. Soc.* **2017**, *139*, 2577, <https://doi.org/10.1021/jacs.6b12840>.
- [50] W. M. Akhtar, R. J. Armstrong, J. R. Frost, N. G. Stevenson, T. J. Donohoe, *J. Am. Chem. Soc.* **2018**, *140*, 11916, <https://doi.org/10.1021/jacs.8b07776>.
- [51] R. J. Armstrong, W. M. Akhtar, T. A. Young, F. Duarte, T. J. Donohoe, *Angew. Chem. Int. Ed.* **2019**, *58*, 12558, <https://doi.org/10.1002/anie.201907514>.
- [52] A. Grozavu, H. B. Hepburn, P. J. Smith, H. K. Potukuchi, P. J. Lindsay-Scott, T. J. Donohoe, *Nat. Chem.* **2019**, *11*, 242, <https://doi.org/10.1038/s41557-018-0178-5>.
- [53] B. Marinic, H. B. Hepburn, A. Grozavu, M. Dow, T. J. Donohoe, *Chem. Sci.* **2021**, *12*, 742, <https://doi.org/10.1039/D0SC05656A>.
- [54] M. Kischkewitz, B. Marinic, N. Kratena, Y. Lai, H. B. Hepburn, M. Dow, K. E. Christensen, T. J. Donohoe, *Angew. Chem. Int. Ed.* **2022**, *61*, e202204682, <https://doi.org/10.1002/anie.202204682>.
- [55] A. J. Day, T. C. Jenkins, M. Kischkewitz, K. E. Christensen, D. L. Poole, T. J. Donohoe, *Org. Lett.* **2023**, *25*, 614, <https://doi.org/10.1021/acs.orglett.2c04149>.
- [56] Y. Park, Y. Kim, S. Chang, *Chem. Rev.* **2017**, *117*, 9247, <https://doi.org/10.1021/acs.chemrev.6b00644>.
- [57] J. Lee, S. Jin, D. Kim, S. H. Hong, S. Chang, *J. Am. Chem. Soc.* **2021**, *143*, 5191, <https://doi.org/10.1021/jacs.1c01524>.
- [58] P. Coppens, *Struct. Dyn.* **2017**, *4*, 032102, <https://doi.org/10.1063/1.4975301>.
- [59] C. S. Higman, J. A. M. Lummiss, D. E. Fogg, *Angew. Chem. Int. Ed.* **2016**, *55*, 3552, <https://doi.org/10.1002/anie.201506846>.
- [60] G. St-Pierre, A. H. Cherney, W. Chen, X. Dong, P. K. Dornan, D. J. Griffin, K. N. Houk, J. B. Lin, S. Osgood, M. V. Silva Elipse, H. C. Timmons, Y. Xie, J. S. Tedrow, O. R. Thiel, A. G. Smith, *Org. Process Res. Dev.* **2021**, *25*, 442, <https://doi.org/10.1021/acs.oprd.0c00416>.
- [61] M. G. Beaver, X. Shi, J. Riedel, P. Patel, A. Zeng, M. T. Corbett, J. A. Robinson, A. T. Parsons, S. Cui, K. Baucom, M. A. Lovette, E. Içten, D. B. Brown, A. Allian, T. G. Flick, W. Chen, N. Yang, S. D. Walker, *Org. Process Res. Dev.* **2020**, *24*, 490, <https://doi.org/10.1021/acs.oprd.0c00052>.
- [62] S. Woo, R. A. Shenvi, *Acc. Chem. Res.* **2021**, *54*, 1157, <https://doi.org/10.1021/acs.accounts.0c00791>.
- [63] J. J. Roach, Y. Sasano, C. L. Schmid, S. Zaidi, V. Katritch, R. C. Stevens, L. M. Bohn, R. A. Shenvi, *ACS Cent. Sci.* **2017**, *3*, 1329, <https://doi.org/10.1021/acscentsci.7b00488>.
- [64] S. Woo, R. A. Shenvi, *Nature* **2022**, *606*, 917, <https://doi.org/10.1038/s41586-022-04840-9>.
- [65] S. Woo, E. M. Landwehr, R. A. Shenvi, *Tetrahedron* **2022**, *126*, 133064, <https://doi.org/10.1016/j.tet.2022.133064>.
- [66] M. Joost, A. Amgoune, D. Bourissou, *Angew. Chem. Int. Ed.* **2015**, *54*, 15022, <https://doi.org/10.1002/anie.201506271>.
- [67] A. Zeineddine, L. Estévez, S. Mallet-Ladeira, K. Miqueu, A. Amgoune, D. Bourissou, *Nat. Commun.* **2017**, *8*, 565, <https://doi.org/10.1038/s41467-017-00672-8>.
- [68] M. Rigoulet, O. Thillaye du Boullay, A. Amgoune, D. Bourissou, *Angew. Chem. Int. Ed.* **2020**, *59*, 16625, <https://doi.org/10.1002/anie.202006074>.
- [69] J. Rodriguez, D. Vesseur, A. Tabey, S. Mallet-Ladeira, K. Miqueu, D. Bourissou, *ACS Catal.* **2022**, *12*, 993, <https://doi.org/10.1021/acscatal.1c04580>.
- [70] F. Neese, *Coord. Chem. Rev.* **2009**, *253*, 526, <https://doi.org/10.1016/j.ccr.2008.05.014>.
- [71] V. Barone, S. Alessandrini, M. Biczysko, J. R. Cheeseman, D. C. Clary, A. B. McCoy, R. J. DiRisio, F. Neese, M. Melosso, C. Puzzarini, *Nat. Rev. Methods Primer* **2021**, *1*, 38, <https://doi.org/10.1038/s43586-021-00034-1>.
- [72] R. Izsák, A. V. Ivanov, N. S. Blunt, N. Holzmann, F. Neese, *J. Chem. Theory Comput.* **2023**, *19*, 2703, <https://doi.org/10.1021/acs.jctc.3c00122>.
- [73] S. Chatterjee, I. Harden, G. Bistoni, R. G. Castillo, S. Chhabra, M. van Gastel, A. Schnegg, E. Bill, J. A. Birrell, B. Morandi, F. Neese, S. DeBeer, *J. Am. Chem. Soc.* **2022**, *144*, 6, 2637, <https://doi.org/10.1021/jacs.1c11083>.