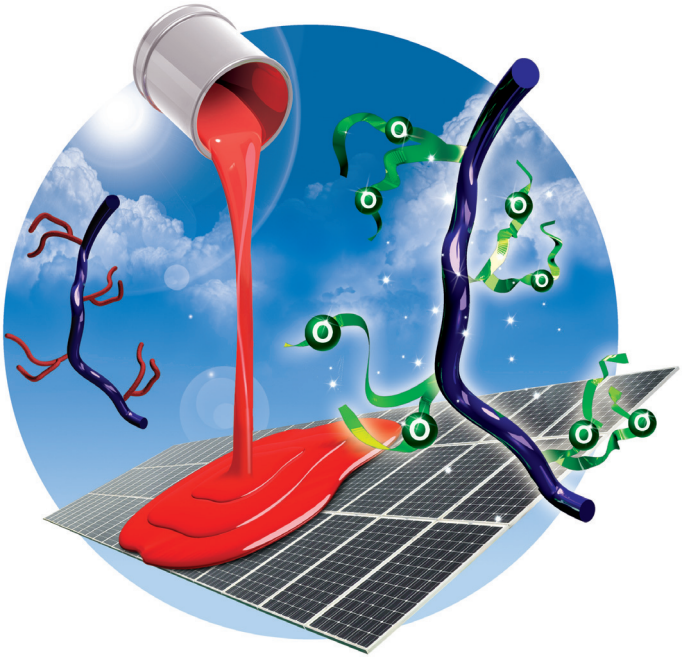
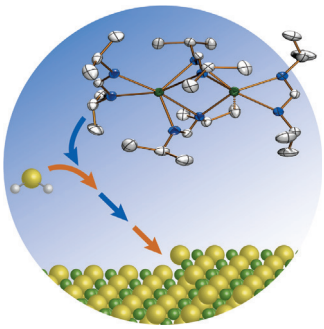
Angewandte International Edition Chemie

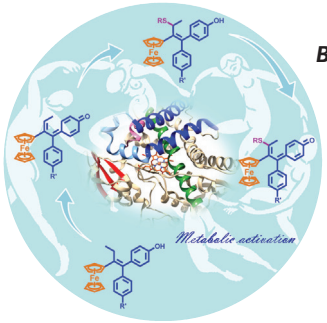


... of conjugated polymers is their solution processability with low cost. Conjugated polymers typically have flexible alkyl side chains for solubility in organic solvents, and J. Liu, L. Wang, and co-workers report in their Communication on page 10376 ff. soluble conjugated polymers bearing novel side chains, branched oligo(ethylene glycol). These polymers can be used in solution-processed polymer solar cells with high efficiency and near-IR response.

Atomic Layer Deposition

The use of volatile dimeric calcium(II) amidinate complexes as highly effective ALD precursors for the synthesis of uniform CaS thin films is reported by R. G. Gordon et al. in their Communication on page 10228 ff.





Bioinorganic Chemistry

In their Communication on page 10431 ff., G. Jaouen and co-workers describe the synthesis and behavior of organometallic antiproliferative compounds resulting from the addition of thiols to ferrocenyl quinone methides.

Skeletal Rearrangements

The first total synthesis of calophyline A is reported by L. Zu and co-workers in their Communication on page 10483 ff. An aza-pinacol rearrangement served as the key strategy in the synthesis.

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Service

Author Profile

"My favorite food is dumplings. My favorite motto is "Where there's a will, there is a way". …"
This and more about Xiaoyuan (Shawn) Chen can be found on page 10180.

News

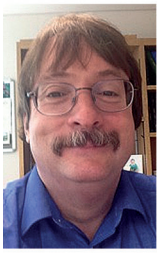

I. J. S. Fairlamb


T. Wirth


V. M. Rotello


J. A. Murphy


A. Weller


R. E. P. Winpenny

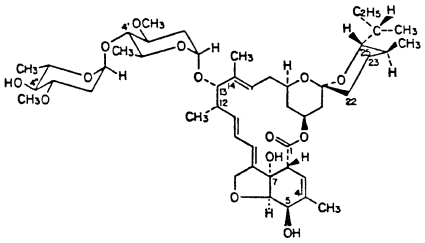

M. S. Hill


J. Zhu

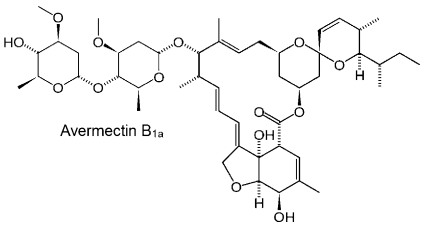

A. J. Wilson


H. Wennemers

Nobel Lectures



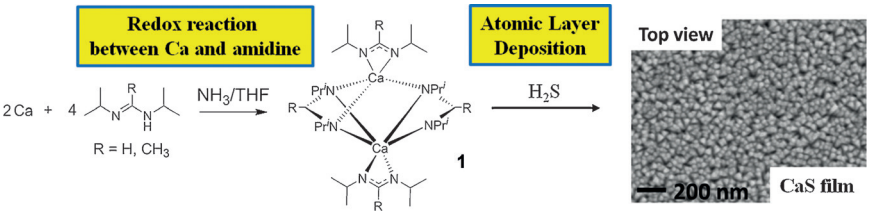
Parasitic diseases including river blindness and lymphatic filariasis affect hundreds of millions of people annually. The discovery of the drug ivermectin has provided humankind with a powerful new means to combat these severe diseases. To a very large extent the drug was brought about by "simple" science.



Japanese soil was the origin of one of the most important drugs of the world: ivermectin. No other drug has such importance for the health of millions of people, particularly in the poor regions of the world. The discovery of the parent compounds of the avermectines is described first hand by S. Ōmura.

Malaria has long been a devastating and life-threatening global epidemic disease in human history. Artemisinin, the active substance against malaria, was first isolated and tested in the 1970s in China. The important role played by traditional Chinese medicine in the discovery of artemisinin is described by Y. Tu in her Nobel Lecture.

Communications



Fling the window open: Dimeric amidinate complexes **1** were obtained as volatile white crystals from a redox reaction between Ca metal and amidine ligands (see scheme). The vapor of the formamidinate complex was used for the synthesis of conformal and uniform polycrystalline CaS films by ALD. With this complex, the ALD window was considerably wider and lower in temperature (150–280 °C) than that observed with the most commonly used ALD precursor.

For the USA and Canada:
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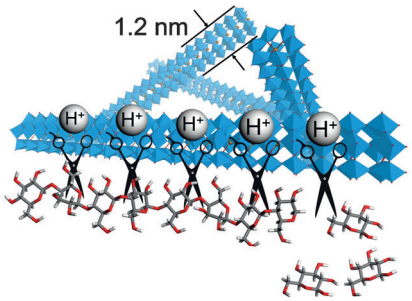
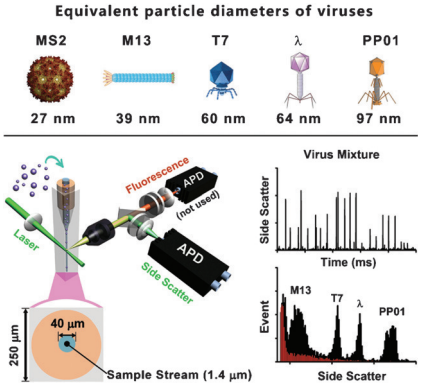


A molecular wire based on tungsten oxide with a diameter of 1.2 nm was synthesized. Acid sites were created in aqueous solution by calcination without collapse of the molecular wire structure. This material was applied for the hydrolysis of cellulosic biomass to produce hexose.

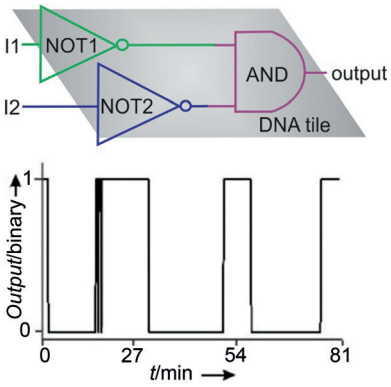
Molecular Wires

Virus detection: A laboratory-built high-sensitivity flow cytometer enables the precise quantification of the elastically scattered light intensity of individual viral particles with diameters down to 27 nm. This label-free approach provides a statistically reliable size distribution profile in 2–3 min, and a mixture of the bacteriophages M13, T7, λ, and PP01 could be baseline-resolved.

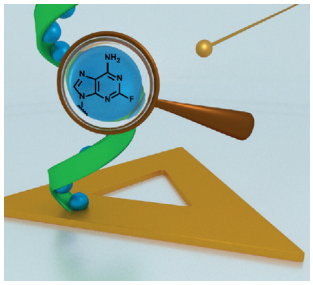


Light-Scattering Detection

AND and NOR on DNA: Arrays of communicating DNA logic gates integrated in a single DNA tile were produced. The gates can process nucleic acid inputs in a reusable format.

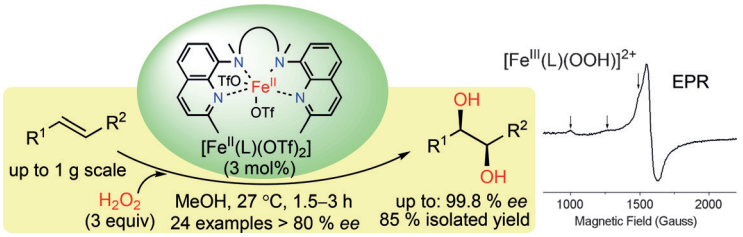


Nucleic Acid Computation

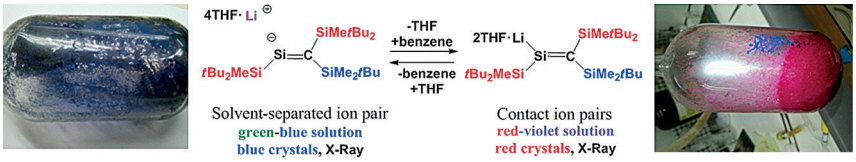


Breaking DNA: Strand breakage in DNA modified with 2-fluoroadenine induced by low-energy electrons is quantified using a DNA origami-based technique. The strand-break enhancement factor was in a similar range for all investigated electron energies.

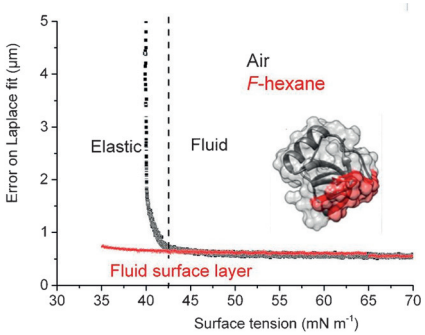
DNA Radiosensitization



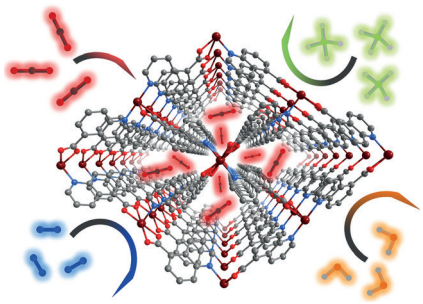
Earth-abundant ingredients: $[Fe^{II}(L)(OTf)_2]$-catalyzed asymmetric *cis*-dihydroxylation of alkenes in a limiting amount with H_2O_2 as a terminal oxidant produces *cis*-diols in up to 99.8 % *ee* with 85 % yield. This "$[Fe^{II}(L)(OTf)_2] + H_2O_2$" method is applicable to both electron-deficient and -rich alkenes. Mechanistic studies suggest involvement of a chiral $[Fe^{III}(L)(OOH)]^{2+}$ active species.



As changeable as a chameleon: A reversible interconversion of a solvent separated and contact ion pair occurs by solvent exchange for R′RC=SiRLi. Characterization data, including the X-ray crystallographic structures, are detailed for these chromatically changeable species.

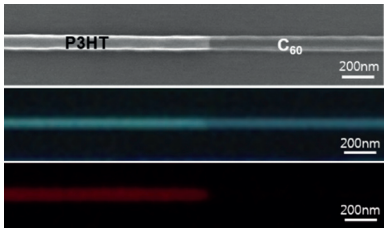


No-trouble microbubbles: A fluorocarbon gas prevents the fluid-to-solid state transition in HFBII hydrophobin 2D films. This new phenomenon allows the preparation of size-controlled, stable, and echogenic HFBII microbubbles with the potential for ultrasound imaging.

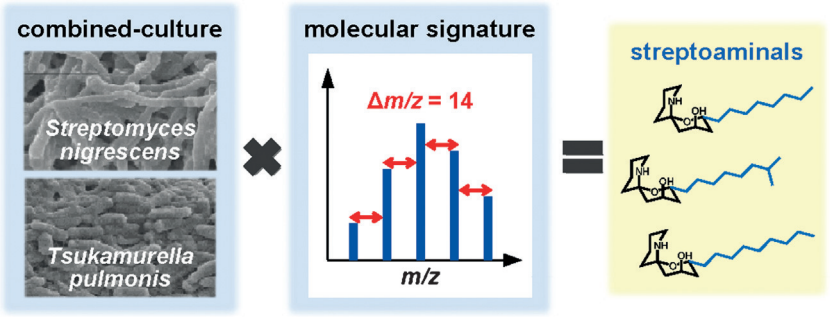


Sieves you right: Crystal engineering of supramolecular isomers of $[Cu(quinoline\text{-}5\text{-}carboxyate)_2]_n$ metal–organic materials enables the right pore-chemistry for ultra-high CO_2/N_2 and CO_2/CH_4 selectivity even in the presence of water vapor.

Junction box: Single-crystal organic axial P3HT/C_{60} p–n heterojunction nanowires each having a well-defined junction region were fabricated by means of inkjet-assisted nanotransfer printing and were exploited for direct observation, by means of scanning photocurrent microscopy, of charge separation and depletion width in the junction region under external electric fields.

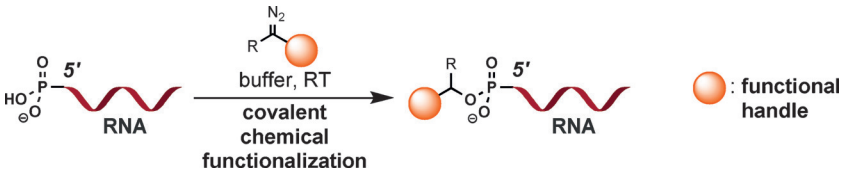


Molecular Electronics



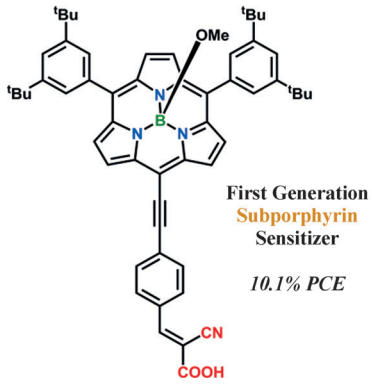
More than the sum of the parts: New antimicrobials were discovered using two approaches: the combined-culture method, and molecular signature analysis by mass spectrometry.

Natural Products



Conditions for selective alkylation of the 5′-phosphate of native RNA in aqueous media are reported. This method was applied to functionalize an oligonucleotide with both biotin and a small molecule that endowed the RNA with binding affinity to the eukaryotic initiation factor 4E (eIF4E), thus confirming the ability to modulate RNA properties and suggesting applications in mRNA therapy.

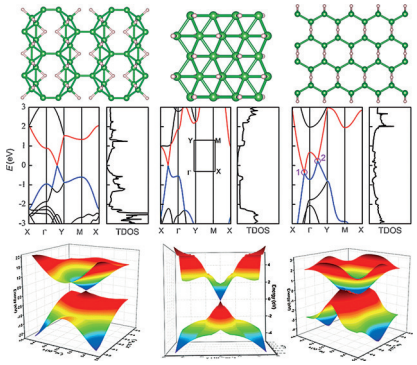
Nucleotide Labelling

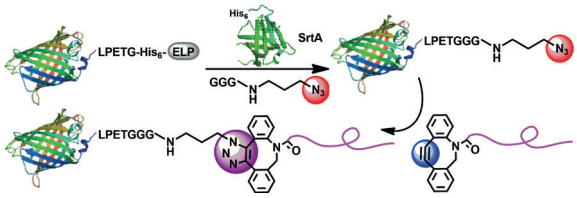


Sensitivity training: The first generation of subporphyrinatoboron(III)-based molecular sensitizers were tested in dye-sensitized solar cells (DSSCs). The most advanced prototype achieved a photon-to-current conversion efficiency value of 10.1%. Such an astonishing figure suggests the potential for subporphyrinatoboron compounds in the field of DSSCs.

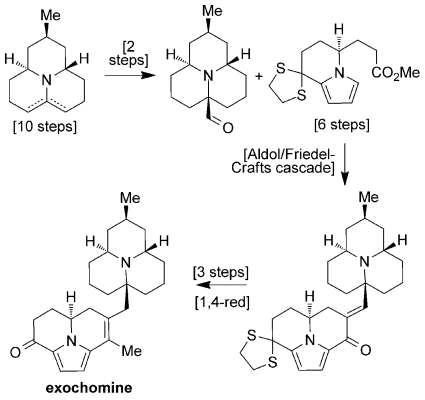
Sensitizers

In an attempt to stabilize 2D boron layers, DFT and a global minimum search with the particle-swarm optimization method were used to predict four stable 2D boron hydride layers, namely *C2/m*, *Pbcm*, *Cmmm*, and *Pmmn* sheets. All of these structures are dynamically stable and possess a Dirac cone feature with massless Dirac fermions. The Fermi velocities for the *Pbcm* and *Cmmm* structures are even higher than that of graphene.

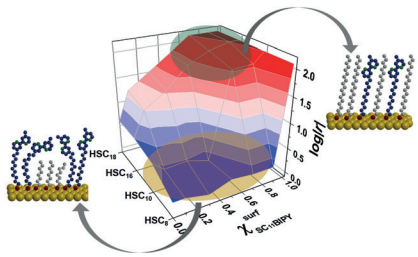




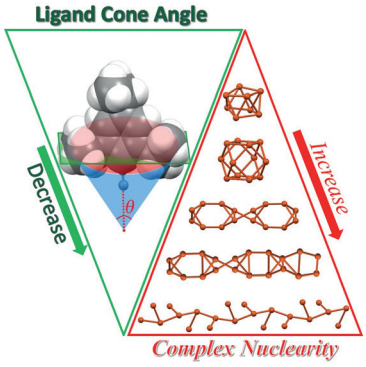
The site-specific and stoichiometric synthesis of protein/peptide–polymer therapeutics in high yield is enabled by a modular method that is based on a combination of recombinant expression, enzyme-mediated ligation, and click chemistry. This approach is suitable for the conjugation of structurally diverse polymers to various protein and peptide drugs.



Challenging chirality: Use of a distinct synthetic strategy to address the challenges in merging two different halves bearing a chiral center at their merger point has enabled access to the alkaloid exochomine in 16 steps. Key operations include the functionalization of a hindered iminium precursor, a unique aldol-based coupling cascade, and a robust protocol for 1,4-reduction in a hindered context where numerous side-reactions can occur.

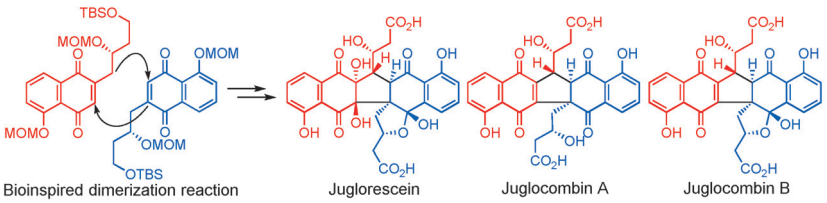


Rectifying defects: A detailed study of the electrical behavior of binary surface-assembled monolayers (SAMs) composed of an organic rectifier, SC_{11}BIPY, and non-rectifying *n*-alkanethiolate diluents shows that the gradient behavior of rectification can be finely tuned by controlling the structure (specifically, the molecular length) of the diluent.



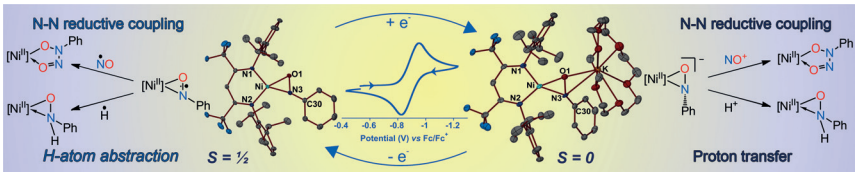
Knowing all the angles: By varying the steric bulk of alkynyl ligands, a Cu^{I} alkynyl polymer (Cu_{∞}) and clusters with various nuclearities (Cu_{4n}, $n = 2$–5) were formed and structurally characterized. Based on the crystal structures, a method to measure the cone angle of alkynyl ligands for evaluating their steric properties was proposed. The nuclearity of the complex was found to increase with decreasing alkynyl ligand cone angle.

Alkynyl Complexes



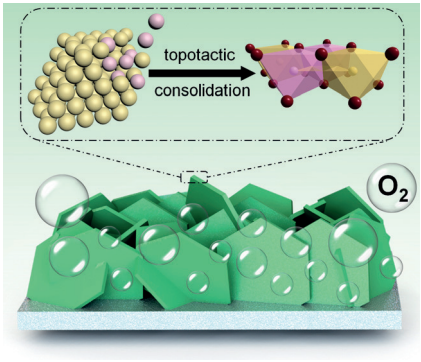
A jugl-ing act: Total syntheses of the natural naphthoquinone dimers juglorescein and juglocombins A and B were achieved through a bioinspired dimerization reaction. From known starting materials, juglorescein was synthesized in nine steps and in 11% overall yield, and the common derivative of juglocombins A and B was synthesized in 14 steps and 3% overall yield. The relative and absolute configurations of the compounds were determined.

Fused-Ring Systems



Isolation and characterization of two interconvertible reduced forms of the nitrosobenzene (PhNO) ligand bound to a common nickel(II) site reveals detailed structure–reactivity relationships reminiscent of reduced forms of dioxygen (O_2) at mononuclear sites, including H-atom abstraction reactivity.

Nitroxyl Model Complexes

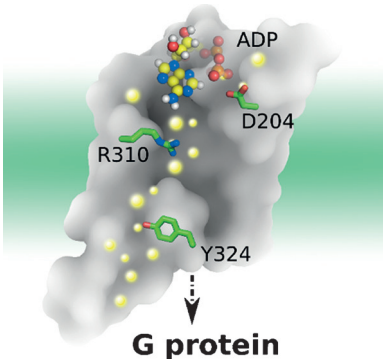


Tactical topology: A topotactic consolidation of cobalt and zinc constituents into monocrystalline CoZn hydroxide nanosheets is demonstrated for direct electrochemical oxygen evolution reactions.

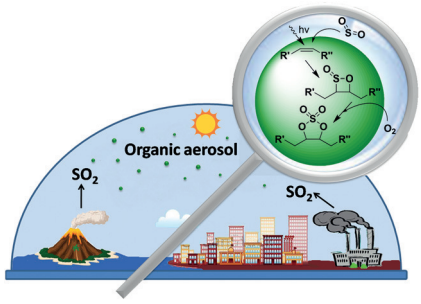
Electrode Materials

Membrane Proteins

When the agonist ADP binds to the G-protein-coupled receptor $P2Y_1R$, it induces breakage of the ionic lock and increases the surface-accessible surface area, leading to a bulk water influx into the binding pocket. Consequently, the rotamer of highly conserved $Y324^{7.53}$ undergoes a molecular switch and a continuous water channel forms inside the receptor resulting in $P2Y_1R$ activation.

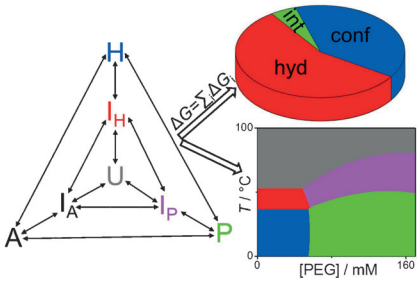


Atmospheric Chemistry



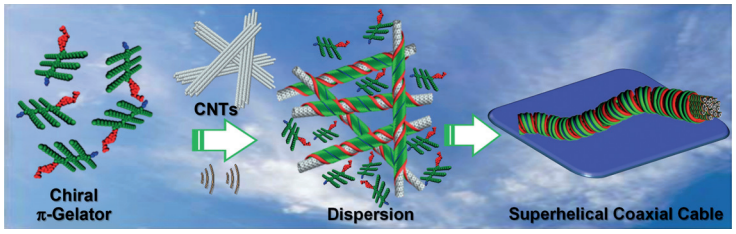
Atmospheric: Sulfur dioxide reacts with a range of fatty acids and long-chain alkenes to lead to organosulfur products. This reaction, which even takes place in the presence of ozone, is enhanced by light. The reaction products have the same composition as organosulfur compounds that have been detected in atmospheric aerosols.

G-Quadruplexes

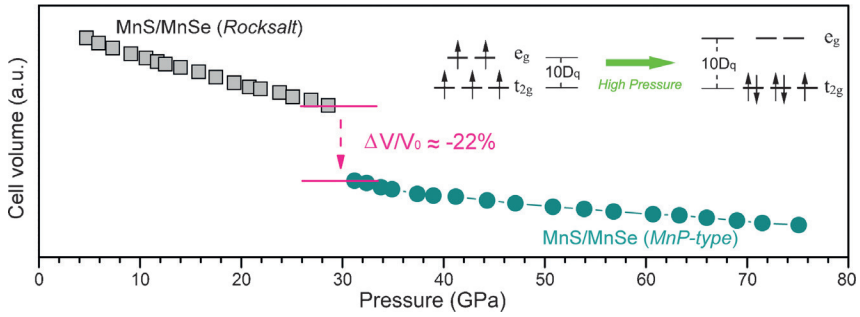


Thermodynamic analysis has enabled the construction of phase diagrams for describing the complex conformational phase space of a human telomere repeat DNA fragment. The analysis clarifies the driving forces for quadruplex folding and interconversion over a wide range of temperatures, salt, and co-solute concentrations and demonstrates their effect on the DNA structural features.

Chiral Carbon Nanocables

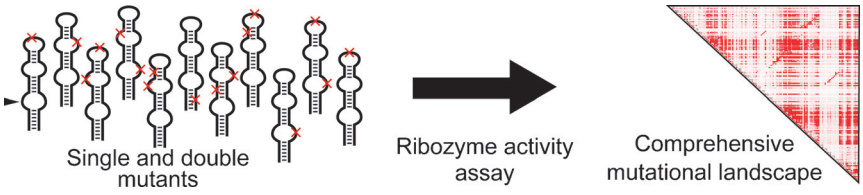


All wrapped up: The interaction of a chiral π-gelator with carbon nanotubes (CNTs) led to 20-fold amplification of the molecular chirality well below the critical aggregation concentration. Helical wrapping of the gelator molecules around the nanotubes led to thick helical fibers composed of individually wrapped and coaxially aligned CNTs (see picture).



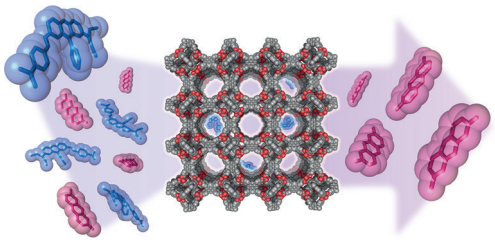
Under pressure: Giant lattice collapses during the pressure-driven phase transition in manganese chalcogenides are associated with the formation of intermetallic bonds and high-to-low spin state transition.

Manganese Chalcogenides



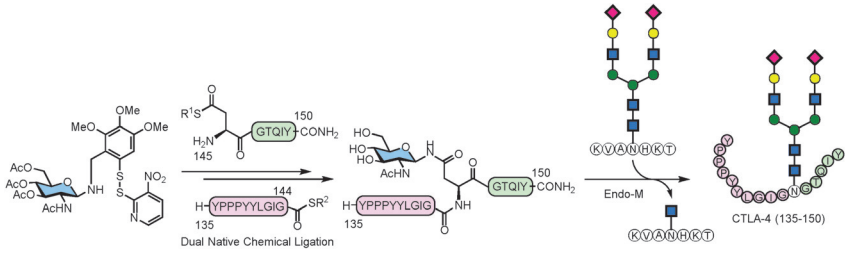
Ribozyme assay by sequencing: Deep sequencing was used to measure the activity of a self-cleaving ribozyme and all of its single and double mutants (a total of 10296 mutants), revealing interesting features of the mutational landscape.

Ribozymes



Stuck on U: Large cationic dyes and enzymes are adsorbed selectively over their anionic counterparts by a water-stable anionic mesoporous metal–organic framework (MOF) based on uranium.

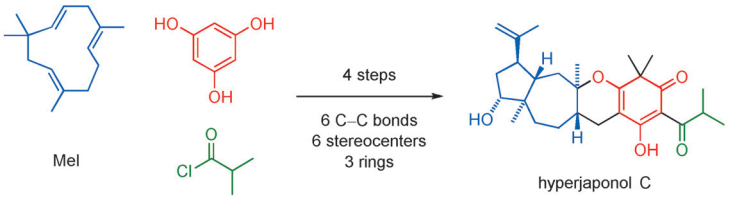
Uranium MOFs



A practical approach towards *N*-glycopeptide synthesis using an auxiliary-mediated dual native chemical ligation (NCL) has been developed. The first NCL connects an *N*-linked glycosyl auxiliary to the thioester side chain of an *N*-terminal aspartate oligopeptide. This intermediate undergoes a second NCL with a *C*-terminal thioester oligopeptide. Mild cleavage provides the desired *N*-glycopeptide.

N-Glycopeptide Synthesis

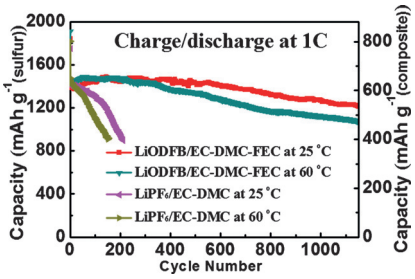
Biomimetic Synthesis



Chemical mimicry: A biomimetic oxidative hetero-Diels–Alder reaction was employed in the total syntheses of hyperjapones A–E. Chemical mimicry of the proposed biosynthetic pathway for the conversion of hyperjapone A into hyperjaponol C allowed a concise total synthesis of hyperjaponol C to be completed in just four steps.

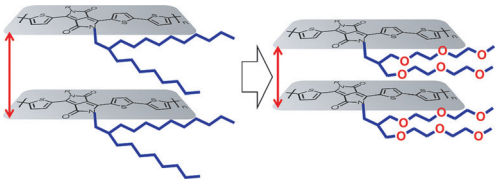
Lithium–Sulfur Batteries

Energy storage: A lithium–sulfur battery system was designed using a carbonate-based electrolyte which not only overcomes the challenges of cyclability and life time at the lithium anode, but also matches the pyrolyzed polyacrylonitrile sulfur composite (S@pPAN) cathode perfectly. The battery system shows extraordinary electrochemical performances (see picture).



Conjugated Polymers

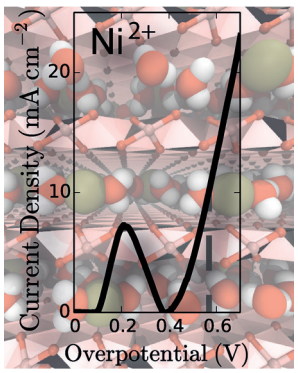
Front Cover

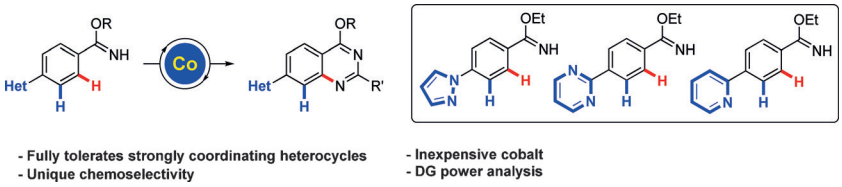


Branched oligo(ethylene glycol) (OEG) was used as side chains of conjugated polymers. Compared to typical alkyl side chains, the branched OEG side chains led to smaller π-π distance of polymer backbone, redshifted absorption spectra, enhanced charge carrier mobilities, and higher dielectric constants. The resulting polymers exhibited outstanding photovoltaic performance in polymer solar cells.

Oxygen Evolution Reaction

Confined interlayer waters: Tailoring the structure of interlayer water in birnessite by intercalating Ni^{2+} ions enhances electron transfer thus improving oxygen evolution reaction (OER) catalysis. These results could aid the synthesis of other OER catalysts that utilize layered or nanoporous materials.

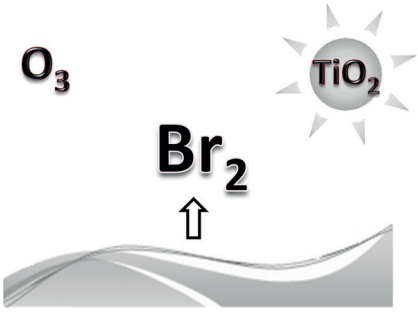




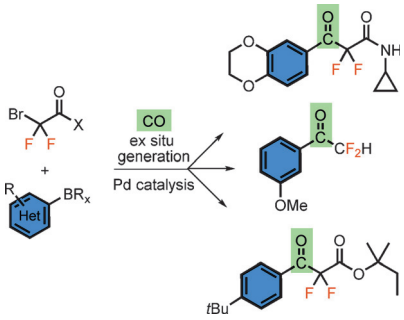
Strongly coordinating nitrogen heterocycles are fully tolerated by a versatile cobalt-catalyzed C–H amidation method, which provides access to structurally complex quinazolines. The powers of various directing groups in cobalt-catalyzed C–H activation were thus delineated.

C–H Activation

Brimming with bromine: Significant production of bromine was observed when acidic solutions of bromide were treated with a TiO_2 photocatalyst, and/or ozone. Bromine selectivities up to approximately 85 % were obtained with a corresponding atomic mass balance. The general process may be applied at a laboratory scale, or industrially as a cheap, safe, and environmentally sustainable alternative to current production methods.

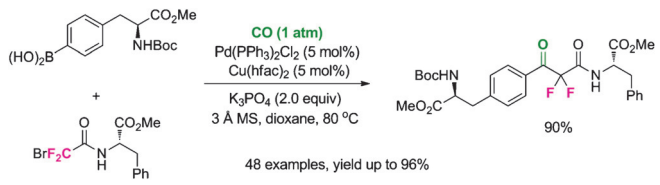


Bromine Production



Yielding to pressure: The title reaction produces aryl α,α-difluoro-β-ketoamides and -esters from readily available difluorinated carboxylic acid derivatives by employing gaseous carbon monoxide. The method features low CO pressures and high functional-group tolerance. The fluorinated products can be transformed into a variety fluoroalkylated structures.

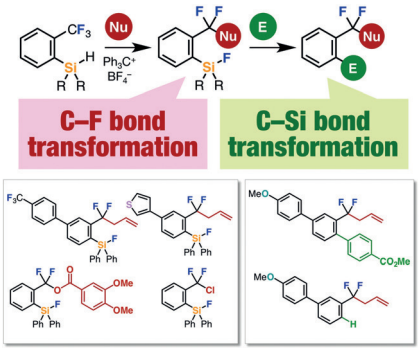
Cross-Coupling



Insertion of CO: A palladium-catalyzed carbonylation reaction of difluoroalkyl halides into ketones was developed (see picture). The resulting difluoroalkyl ketones can serve as versatile building blocks for the synthesis of useful fluorinated compounds.

Carbonylation

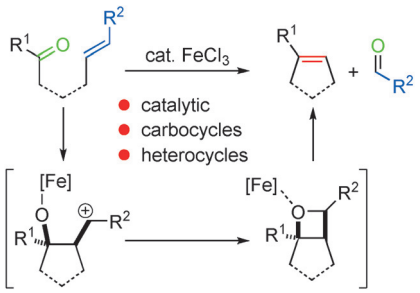
C–F Activation



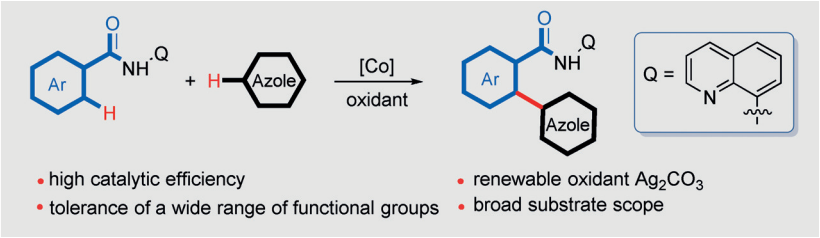
One of the three: The transformation of a single C–F bond of trifluoromethylarenes bearing an *ortho*-hydrosilyl group is described. The activation of the hydrosilyl group with a trityl cation in the presence of nucleophiles enabled selective C–F bond functionalization, for example, by allylation, carboxylation, or chlorination. Further derivatization of the resulting fluorosilylarenes afforded various difluoromethylated arenes.

Metathesis

Ironing it out: The title reaction allows access to a range of carbo-/heterocyclic alkenes. The reaction is proposed to take place by $FeCl_3$-catalyzed oxetane formation followed by retro-ring-opening to deliver the metathesis products.

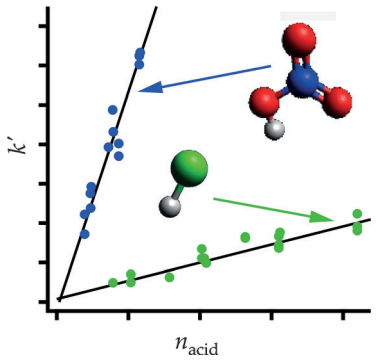


C–C Cross-Coupling

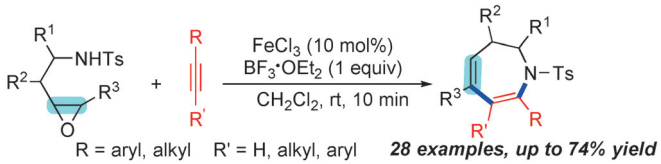


A bidentate 8-quinolinyl ligand assists the cobalt-catalyzed title reaction between two (hetero)arenes exhibiting a broad substrate scope and a high tolerance level for sensitive functional groups. The preliminary mechanistic study suggests that a single electron transfer pathway is operative.

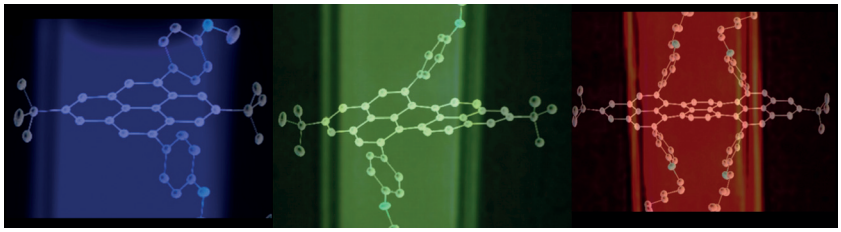
Gas-Phase Reactions



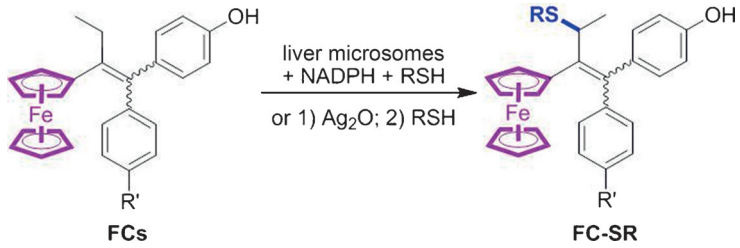
Novel sink for Criegee intermediates: The rate constants for the reaction of the simplest Criegee intermediate, CH_2OO, with HCl (in green) and HNO_3 (in blue) were directly measured by broadband transient absorption spectroscopy. Both reactions occur at or near the collision limit, as was also confirmed by quantum-chemical calculations.



Access all azepines: An $FeCl_3$ and $BF_3{\cdot}OEt_2$ co-catalyzed tandem hetero-[5+2] cycloaddition of 2-(2-aminoethyl)-oxiranes with alkynes is presented. This method provides a rapid and practical access to 2,3-dihydro-1*H*-azepines with exquisite chemo- and regiocontrol. The reaction is simple and has broad substrate scope and excellent functional-group tolerance.



Pyrenes with a twist: The synthesis of soluble pyrenes, peropyrenes, and teropyrenes using a two- and fourfold alkyne benzannulation reaction promoted by Brønsted acid is reported. The compounds show an expected red shift in absorbance and emission as a function of conjugation length with quantum yields of up to 62%. X-ray crystallographic analysis of these polycyclic aromatic hydrocarbons shows significant twisting of the aromatic core, thus demonstrating how flexible nanographenes can be.

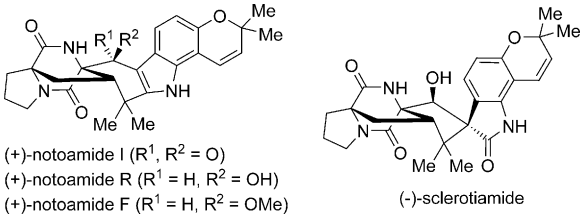


FCs FC-SR

Ferrociphenol quinone methide–thiol adducts are potent organometallic antiproliferative compounds that result from the addition of thiols to ferrocenyl quinone methides. These FC-SR adducts were identified upon metabolism of ferrociphenols (FCs) by liver microsomes in the presence of NADPH and thiols. They display unique oxidative behaviors that may inspire development of new organometallic anticancer drugs.

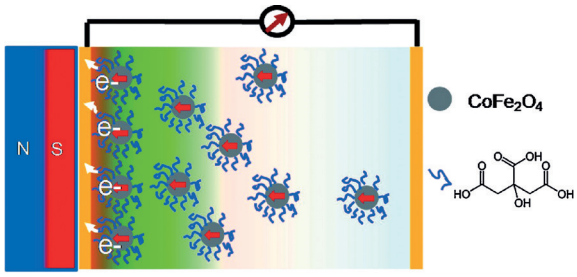
Angewandte International Edition Chemie

Indole Alkaloids



Just a hop, skip, and a jump: The title compounds were synthesized in only 10–12 steps from the Seebach acetal. The synthetic approach features an oxidative aza-Prins cyclization to construct the bicyclo[2.2.2]diazaoctane in a highly stereoselective manner and a cobalt-catalyzed radical cycloisomerization to build the cyclohexenyl ring.

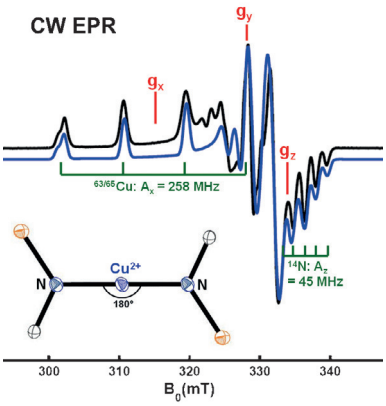
Concentration Cells



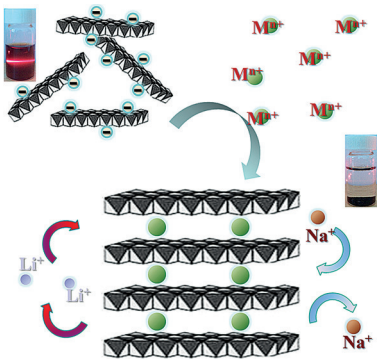
$CoFe_2O_4$ nanocrystals with controlled size and magnetic properties were synthesized. The energy storage performance of concentration cells is dictated by the magnetic characteristics of the cobalt ferrite nanocrystal carriers.

Copper Complexes

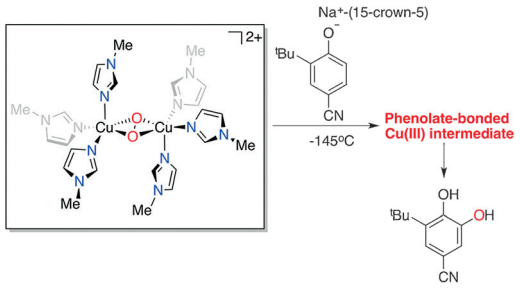
Straight-up copper: The synthesis of the first linear Cu^{II} complex $Cu\{N(SiMe_3)Dipp\}_2$ ($Dipp = C_6H_5$-2,6-Pr^i_2) and its Cu^I counterpart $[Cu\{N(SiMe_3)Dipp\}_2]^-$ is described. The former, studied by EPR spectroscopy, forms through a dispersion force-driven disproportionation, and is the reaction product of a Cu^I halide and $LiN(SiMe_3)Dipp$ in a non-donor solvent. The latter forms by preventing the disproportionation by using the complexing agent 15-crown-5.



Electrochemistry



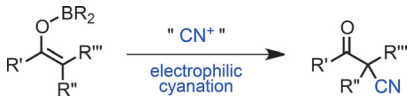
Spoilt for choice: A series of three-dimensional M_xMnO_2 (M = Li, Na, K, Mg, or Co) cathodes with a sandwich structure were obtained by the self-assembly of manganese oxide nanosheets with these metal cations. The intercalated cations influence the capacity and cycling stability of these cathodes for lithium and sodium storage.



Cold copper cores: Three Nτ-imidazole-bonded $Cu^{II}_2O_2$ species were synthesized and characterized at low solution temperatures. These complexes resemble the catalytic cores of tyrosinases, and allowed phenolate-ligated Cu^{III} intermediates during hydroxylation reactions to be probed, providing insights into the enzymatic mechanisms.

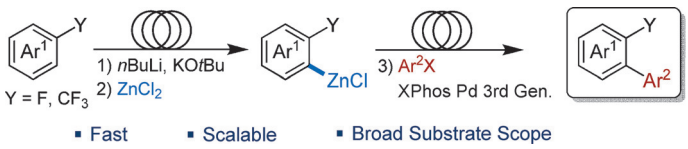
Coordination Chemistry

Plus CN: The title reaction proceeds with readily available cyanating reagents, *N*-cyano-*N*-phenyl-*p*-toluenesulfonamide and *p*-toluenesulfonyl cyanide. Various β-ketonitriles can be prepared by this new protocol, which shows a remarkably broad substrate scope compared to existing methods. The present method also allowed efficient synthesis of β-ketonitriles bearing a quaternary α-carbon center.

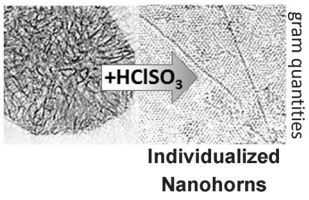


Synthetic Methods

Hey! Ho! Let's flow! A highly regioselective functionalization of fluoro- and trifluoromethyl-substituted arenes and pyridines under continuous-flow conditions is described. This method telescopes a directed lithiation, a zincation, and a Negishi cross-coupling into a single process to provide diversely functionalized, pharmaceutically relevant biaryls.



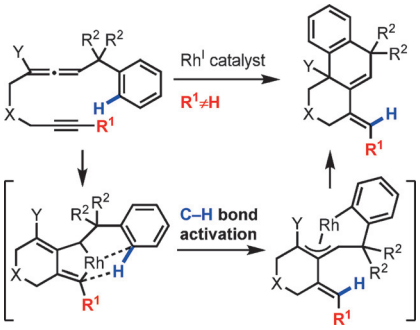
Flow Chemistry



I am an individual: A facile approach for the separation of aggregated carbon nanohorns (CNHs), by treatment with chlorosulfonic acid, leads to p-doped species. The acid induces positive charges on the nanohorns which repel and push the individual nanohorns apart. The method yields gram quantities of free nanohorns.

Carbon Nanohorns

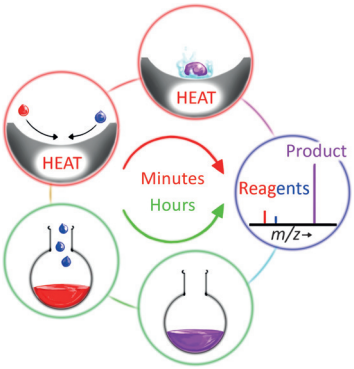
Cycloisomerizations



Hexahydrophenanthrene derivatives were obtained from internal alkynes with a pendant benzylallene moiety through cycloisomerization by C(sp^2)–H bond activation. The reaction likely proceeds by formation of a rhodabicyclo[4.3.0] intermediate, σ-bond metathesis between a C(sp^2)–H bond on the benzene ring and the C(sp^2)–Rh^{III} bond, and isomerization between three σ-, π-, and σ-allylrhodium(III) species.

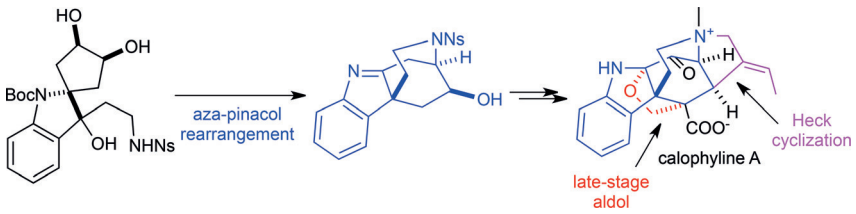
Reaction Kinetics

Chemical reactions can be accelerated in Leidenfrost levitated droplets in processes that are similar to reaction acceleration in charged microdroplets produced by electrospray ionization. Acceleration factors of 2 to 50 compared to the corresponding bulk-phase reactions were achieved for a range of transformations.



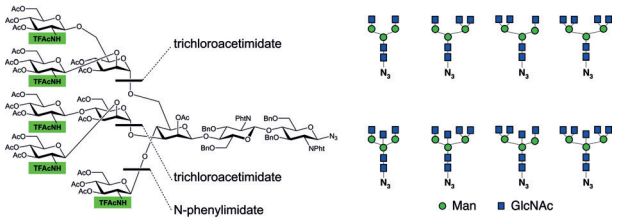
Natural Products

Back Cover

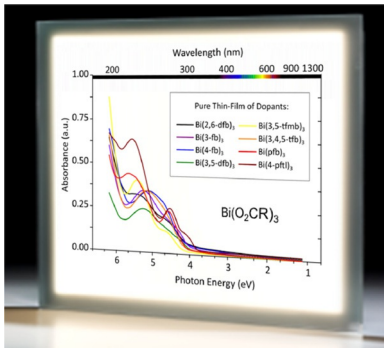


It has a nice ring: The first total synthesis of calophyline A is reported. The synthetic route features several key transformations, including an aza-pinacol rearrangement to construct the nitrogen-containing bridged [3.2.2] bicycle, a Heck cyclization to assemble the fused 6/5/6/5 ring system, and a challenging late-stage aldol reaction to generate both a neopentyl quaternary stereogenic center and an oxygen-containing bridged [3.2.1] bicycle.

Glycans



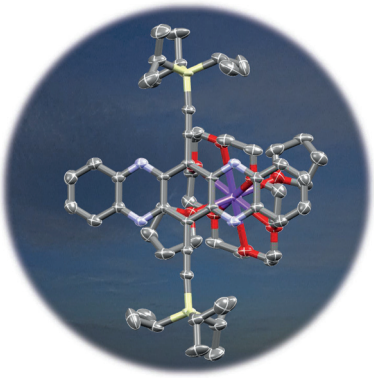
Bisecting á la carte: A general and robust modular approach to bisected N-glycans was established based on a unified protecting-group pattern. The switch to N-TFAc protection of the donors for the antennae provides high yields for the difficult late-stage introduction of a bisecting GlcNAc. Regardless of the number of antennae, a judicious choice of imidate activation permits the highly efficient one-pot synthesis of bisected N-glycans.



Bi doping: Ten new efficient p-dopants for conductivity doping of organic semiconductors for OLEDs are identified. The key advantage of the electrophilic tris(carboxylato)bismuth(III) compounds is the unique low absorption of the resulting doped layers. The combination of this feature with their low fabrication cost, volatility, and stability, make these materials very attractive as dopants in organic electronics.

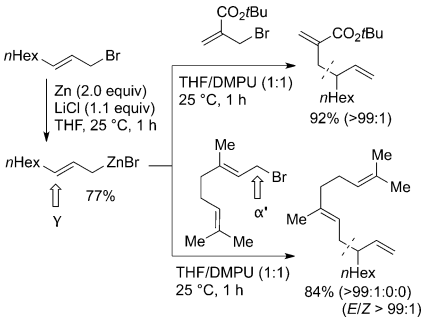
Organic Semiconductors

Charged but not pinned down! The reduction of the symmetrical tetraazapentacene with potassium metal in THF gives the radical anion, a species critical in charge transport in field effect transistors. The negative charge is shown to be equally distributed over the whole molecule and not localized or pinned on the electronegative nitrogen atoms.

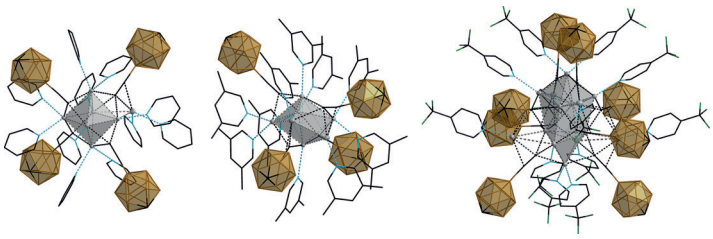


Azapentacene

One of four possible products: Cross-coupling reactions of allylic zinc halides with allylic bromides provide 1,5-dienes with high regioselectivity. Various functional groups (ester, nitrile) are tolerated. Propargylic and benzylic halides can be used in this transformation. DFT calculations confirm the importance of LiCl for the efficient cross-coupling.



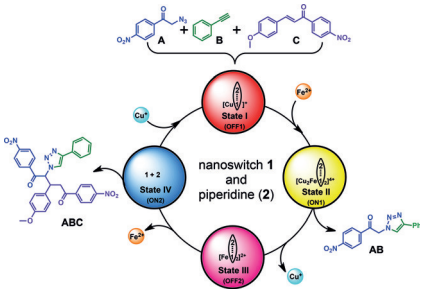
Synthetic Methods



Six silver(I) clusters with five electronically different pyridine ligands were obtained starting from the silver(I) alkynyl $\{Ag_2(12\text{-}C{\equiv}C\text{-}closo\text{-}1\text{-}CB_{11}H_{11})\}_n$. All of the clusters show room-temperature phosphorescence, which is highly unusual for this class of compounds. A distorted pentagonal bipyramidal Ag^I_7 cluster with 3,5-lutidine gave a quantum yield of $\Phi = 0.76$, unprecedented for Ag^I clusters.

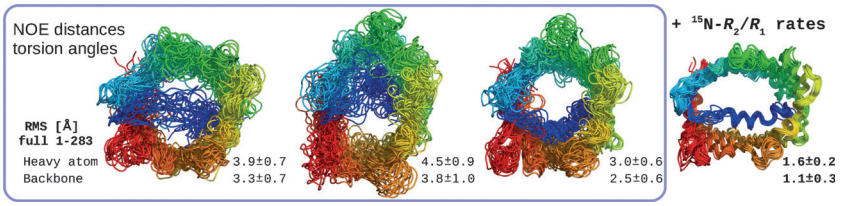
Silver Clusters

Sequential Catalysis



Connect four: The first nanoswitch with four states can control a sequential transformation **A** + **B** + **C** → **AB** + **C** → **ABC** with 11 components over two complete cycles. The cycle proceeds stepwise along the switching states OFF1 → ON1 (click reaction: **A** + **B** → **AB**) → OFF2 → ON2 (Michael addition: **AB** + **C** → **ABC**) → OFF1 (see scheme). The system's preformance is superior to that of systems with only two switching states.

NMR Spectroscopy



Just relax: ^{15}N nuclear magnetic relaxation was used to determine the 3D structure of a challenging membrane protein. The structure of the human voltage-dependent anion channel refined to high resolution against relaxation rates shows unique features of an anisotropically shaped barrel and a well-folded N-terminal helix.

Supporting information is available on www.angewandte.org (see article for access details).

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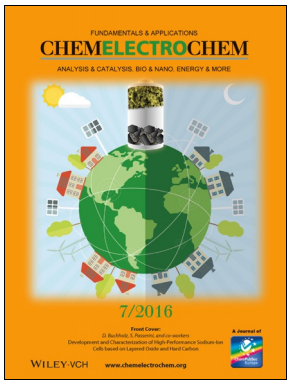

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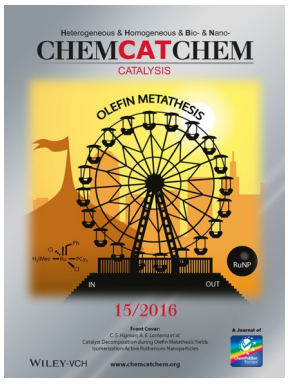

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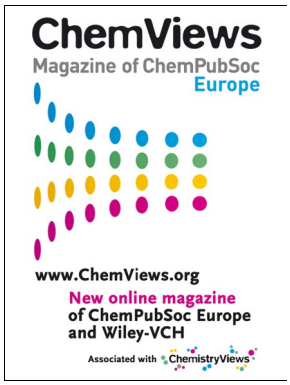

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