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Synthesis and reactivity of ethylene complexes of group 6 and 8 metals

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Ethylene complexes constitute one of the classical families of organometallic compounds, and most of the transition metals are known to coordinate such ligand. In the context of the ethylene-carbon dioxide coupling reaction en route to acrylic acid derivatives, very few complexes have been described to promote such transformation. Only nickel, molybdenum and tungsten compounds bearing one (Ni) or two (Mo, W) ethylene ligands have been described promoting a given reaction toward carbon dioxide.

We have revisited this chemistry with the aim of understanding the \( \text{C}_2\text{H}_4\)-\( \text{CO}_2 \) interaction. With this idea in mind, we have prepared novel tris-ethylene complexes of Mo(0) and W(0) bearing a pincer \( \text{P}-\text{N}-\text{P} \) ligand, and investigated their interaction with carbon dioxide. Preliminary studies have shown that a mono-carbon dioxide, bis(ethylene) Mo(0) complex is formed as the first step, not only in solution but also in the solid state.

In a collaborative effort between our two laboratories, we have also studied dicationic Ru(II) complexes bearing a \( \text{N}-\text{N}-\text{N} \) pincer ligand. Its reactivity toward ethylene has led to unstable bis(ethylene) complexes, also of interest toward carbon dioxide coupling.

Reference

Assembly of Peptides upon Sustainable C–H Functionalization
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Owing to the emergence of peptidomimetics at the forefront of pharmaceutical research and the limited availability of amino acid genetically encoded, the development of new methodologies for the straightforward chemical modification of α-amino carbonyl compounds represents a challenging task of prime scientific interest.\[1\] Although most classical α-functionalization methods are hitherto limited to carbanion chemistry and solid phase techniques, the last years have witnessed the upsurge of catalytic C–H functionalization approaches\[2\] as atom-economic and environmentally friendly means for the direct modification of peptide derivatives. In this communication we will described our latest results on the assembly of α-functionalized glycine derivatives and short peptides. We have developed cobalt-catalyzed selective alkylation and heteroarylation processes for the rapid synthesis of structurally diverse α-amino carbonyl compounds upon activation of the α-C(sp\(^3\))−H bond neighboring to the amino group (Scheme 1, \textit{path a}).\[3\] Likewise, following a related α-C(sp\(^3\))−H oxidation process, an efficient ligand-free Fe-catalyzed oxidative Ugi-type reaction toward the synthesis of α-amino amides from \(N,N\)-dimethylanilines will be disclosed (Scheme 1, \textit{path b}).\[4\]


\textbf{Scheme 1.} Metal-catalyzed synthesis of Ṣ-amino carbonyl compounds.

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\textbf{References}
Direct Arylation of Dipyrrolonaphthyridinediones (DPNDs) Leads to Red-Emitting Dyes with Conformational Freedom

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The series of bis-aryl-dipyrrolonaphthyridinediones (DPNDs) with different substitution patterns have been designed and synthesized via direct arylation methodology. This reaction occurs regioselectively at positions 3 and 9, thus giving a straightforward entry to unique dyes absorbing in the red/far-red region and emitting in the far-red/NIR region. The photophysical properties, such as absorption or fluorescence wavelengths can be controlled via altering the steric hindrance and electronic character of the peripheral aryl group. The fluorescence quantum yields are moderate in the majority of cases and almost independent of changes in the solvent polarity. DPNDs bearing sterically hindered substituents, which prevent free rotation of the phenyl ring, emit stronger fluorescence (~0.60 vs ~0.45). Simultaneously, their absorption and emission bands are blue-shifted compared to unhindered para analogs. We have explained, by means of computational methods, why the introduction of electron-donating substituents has significantly stronger effects on optical properties compared to the presence of electron-withdrawing groups by invoking the electron-accepting character of the dipyrrolonaphthyridinedione. Electrochemical measurements revealed that HOMO and LUMO levels, as well as the electrochemical band gap also depend strongly on the electronic character of the peripheral group.

Orthopalladated complexes from substituted oxazolones, imidazolones and thiazolones, and their photophysical properties

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The synthesis of orthopalladated derivatives of oxazolones, imidazolones and thiazolones is reported. The reaction takes place through a directed C-H bond activation process, by treatment of the free ligands with Pd(OAc)_2 in carboxylic acid as a solvent. The reaction is fully regioselective, because only the ortho-protons of the Ph ring at the 4-position (the arylidene ring) are activated, regardless the substituents at the arylidene ring and the electronic nature of the heterocycle (oxazolone, imidazolone, thiazolone). Standard bidentate and new tridentate systems containing the heterocyclic moiety have been attempted, with excellent results in all cases. In addition, the carboxylate bridges have been changed by a variety of anionic ligands, such as chloride, acetylacetonate, alkynyl, etc, giving a wide variety of dinuclear and mononuclear derivatives.

The photophysical properties of these systems have also been studied, in order to check the influence of the palladium, the nature of the heterocycle, the substituents in the orthopalladated heterocyclic ligand, and the auxiliary ligands in the fluorescence of the resulting complexes.
Gas-Liquid Catellani type Reactions enabled by continuous flow
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The selective activation and functionalization of inert C-H bonds is a great challenge in synthetic chemistry. In 1997 Marta Catellani et al. reported a pioneering strategy to functionalize both the ortho and ipso positions of aryl halides. Over the past two decades the Catellani reaction was intensely investigated, and a variety of compounds has been obtained.

Owing to its wide applicability and versatility, the Catellani reaction might be intriguing towards industrial applications. In this regards, continuous flow is a valuable choice to easily and safely perform a reaction scale-up. During the last years flow technologies have received remarkable attention, their importance is attributed to the many benefits flow possesses with respect to conventional batch transformations. Among these, frequently described advantages are enhanced heat and mass transfer, large scale applications and better mixing. The latter is especially important in multiphase systems.

Gaseous reagents are used in a large stoichiometric excess when batch conditions are employed, because of poor interfacial mixing. This can outcome in longer reaction time, making the process extremely slow. Continuous flow guarantees a high surface area to volume ratio, that allows an increase in mass transfer and thus accelerates reaction kinetics when mass transfer is rate limiting.

Our first issue was to transform the reaction procedures into homogeneous conditions for flow. Our base, K$_2$CO$_3$ which is not completely soluble in the reaction media, was causing issues when translating the reaction to flow. Continuous flow technology, especially micro-flow setup, performs better if solid reagent are avoided. This prevents clogging and ensures an ideal mass transfer. After a careful survey of bases, tetrabutylammonium acetate (TBAA) proved its value by granting full conversion in 2 hours, while being completely miscible in DMF.

\[
\text{Ar}^R + \text{Ar}^R + \text{gas reagent} \rightarrow \text{Ar}^R\text{Ar}^R + \text{R}_2
\]

A new and efficient flow methodology was developed. To test the robustness of the novel approach, different molecules were synthesized employing liquid-liquid conditions. Moreover we devoted specific attention to employ gaseous reagents, which can highly benefit from continuous-flow conditions. Ethylene, propylene and 3,3,3-trifluoro-1-propene were engaged as starting materials, allowing the possibility to insert these moieties in the targeting molecules.

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Halide-Catalysed C-H Amination Reactions

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The development of light-initiated catalytic C-H amination processes (Hofmann-Löffler reactions) has been accomplished using novel halogen-based catalysts that are directly generated from molecular iodine\(^1\) or from ammonium bromide\(^3\) sources. These processes can be tuned to involve either halogen(-I/I) or halogen(I/III) catalyst states. The specific iodine redox cycle depends on the chosen terminal oxidant, which can be an iodine(III) reagent or molecular dioxygen within photocatalysis, and which is commercially available \(m\)CPBA for the bromine redox cycle. The reactions proceed within a unique scenario of two intertwined catalytic cycles with an unprecedented scope including primary, secondary and tertiary C-H bonds. Mechanistic details include the isolation and study of active catalyst derivatives. These accomplishments demonstrate the rich facilities for C-H oxidation catalysis within defined halide redox manifolds.

Graphene Film-Supported Oriented 1.1.1 Gold (0) Versus 2.0.0 Copper (I) Nanoplatelets as Very Efficient Catalysts for Michael Additions

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Metal nanoparticles (MNPs) supported on large surface area solids are widely used as heterogeneous catalysts for a large variety of organic reactions [1]. Theoretical calculations and experimental data suggest that different crystallographic planes of MNPs may exhibit specific activity in catalysis [2]. Therefore, one of the key issues for achieving high selectivities is the control of their preferential facets. In this context, the existing literature already suggests that carbon-nanotubes [3] and, more recently, graphene [4] provide interfaces with MNPs exhibiting specific electronic properties generated by the occurrence of a charge transfer between the carbon nanoform and the MNPs. In this context, we have recently reported a novel one-step pyrolysis procedure for the production of MNPs strongly grafted on few- and multilayer defective graphenes [5].

The catalysts in this study were prepared by pyrolysis of chitosan films containing AuCl₄⁻ or Cu²⁺ ions rendering facet oriented Au and Cu nanoplatelets strongly grafted on defective N-doped graphene films. The number of layers depended on the thickness of the chitosan film precursor. Cu/fli-G undergoes upon exposure to the ambient preferentially oriented (2.0.0) copper(1) oxide nanoplatelets while Au³⁺ renders 1.1.1 oriented Au nanoplatelets (20 nm lateral size, 3–4 nm height) (Au/fli-G). These nanometric films containing oriented nanoplatelets were investigated in the Michael addition reaction, which is one of the oldest and useful C-C bond-forming reactions [6]. This 1,4-addition is typically carried out using basic catalysts. The prepared catalysts were exhaustively characterized using different techniques as powder X-ray diffraction (XRD), Raman spectroscopy, X-ray photoelectron spectroscopy (XPS) and transmission electron microscopy (TEM) [5, 7]. Activity tests were carried out by using aqueous solutions of β-ketoesters as Michael donor (methyl acetoacetate, ethyl acetoacetate; isobutyl acetoacetate, ethyl 2-oxocyclohexanecarboxylate or ethyl 2-oxocyclopentanecarboxylate) and methyl vinyl ketone, as Michael acceptor, at room temperature for 18h and one piece of 1 x 1 cm² plate of Au/fli-G or Cu/fli-G film as catalysts. The recovered products from the liquid phase were extracted with ethyl ethanoate and analyzed by GC-MS.

It has thus been shown that films of oriented 2.0.0 Cu₂O and 1.1.1 Au nanoplatelets grafted onto few-layers graphene exhibit indeed activity in the Michael addition, with TONs higher than those of analogous Cu and Au catalysts adsorbed on graphene. These Cu₂O and Au grafted on graphene also exhibit a remarkable catalytic activity to promote with total selectivity (in the absence of any extrinsic base) the Michael addition of acyclic and cyclic active methylene and methine compounds to α, β-conjugated ketone.

References
Multicopper Cores and MOFs: New Catalysts for Mild Functionalization of Alkane Feedstocks

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This contribution will summarize our recent results on the design, self-assembly synthesis and catalytic application of various multicopper(II) coordination compounds (discrete complexes and metal-organic frameworks) derived from aminoalcohol and carboxylic acid building blocks.[1] The obtained copper(II) products were applied as highly efficient bioinspired (pre)catalysts for: (1) the mild oxidation of different alkanes by hydrogen peroxide into alcohols and ketones ("C–H to C–O functionalization"), and (2) the hydrocarboxylation of gaseous and liquid Cn alkanes, by carbon monoxide, water and potassium peroxodisulfate, into the corresponding Cn+1 carboxylic acids ("C–H to C–C functionalization"). Catalytic efficiency, substrate scope, mechanistic and selectivity features, role of promoters and effects of different reaction parameters will be discussed, with a particular emphasis on unusual promoting role of water in the Cu-catalyzed oxidative functionalization of alkanes. Other examples of functional metal-organic networks and related materials with prospective catalytic applications in C–H functionalization or degradation of organic water pollutants will be presented.[2] Collaborations within the COST CHAOS network will be highlighted.

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References

Artificial Photoenzymes for Solar Photocatalytic Hydrogen Atom Transfer Reactions

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The Mechanism of the Palladium-Catalyzed Aerobic Homocoupling of Alkynes: A more Complex Oxidase-type Reaction

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A combined experimental and computational approach has been used to shed some light on the mechanism of the Pd-catalyzed oxidative homocoupling of alkynes using oxygen as oxidant. Besides its synthetic interest, this reaction is a competitive process in coupling reactions involving terminal alkynes but no detailed study was available so far on how this reaction occurs.

C3 arylation of furfural derivatives via catalytic C-H bond activation

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The development of biorenewable chemical building blocks for chemical based commodities is an important issue. Carbohydrates are valuable resources for the generation of synthetic building blocks. Among them, glucose and xylose can be used without competing with the food sector being known their transformation to the furan functionality such as 5-(hydroxymethyl)furfural(HMF), and furfural respectively.[1] Recently, this team explored the Ru-catalyzed hydrofurylation of alkenes, involving a directed C–H activation at C3 of the furan ring.[2]

Here in, is presented a new functionalization of the biomass derived compounds furfural and HMF at C-3 position (Scheme 1) via catalytic C-H activation directed by temporary pendant group attached to the furan ring as imine via Ru-catalyzed hydroarylation of olefins.
Scheme 1. Overview of the C-3 position activation of furfural and derivatives.

The optimization of reactions conditions were performed and the reaction scope evaluated.[3]
This atom-economical strategy has potential for an array of direct applications in Ru(0)-
catalyzed C–H bond aryla ons using removable direc ng groups

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Process Development@Merck

Philipp Hans Fackler.

Process development paves the way for research substances in becoming valuable and
accessible products. The talk will give a short overview of chemical process development at
Merck with a focus on the organizational set-up and main working areas.