

CulturChem 406

2016-2017

September

Monday Sept 12th
Auditorium Astier 11h

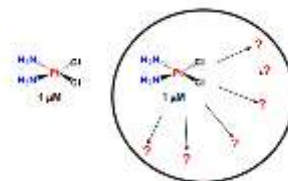


Dan Gibson (Hebrew University, Jerusalem, Israel)

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What do we really know about the mechanism of action of platinum anticancer agents?

Abstract. Cisplatin is one of the most successful and widely used anticancer agents. The accidental discovery of the anticancer activity of the metal complexes, followed by its approval by the FDA, triggered a new field of research – metal complexes as anticancer agents. Decades of intensive research yielded two more platinum complexes that were approved as anticancer drugs – carboplatin and oxaliplatin. As medicinal inorganic chemists who are trying to elucidate the mechanism of action of platinum anticancer complexes, we are interested in following the fate of the platinum complexes in cells. This could lead to a better understanding of the mechanism of action and might allow for the design of superior drugs. The inability to monitor platinum speciation in cells, due to limitations of the current bio-analytical techniques, forces us to rely on simplified model systems that are not necessarily adequate. In this talk we will examine the validity of the hypotheses that are guiding the research in this field, as related to the chemistry of both platinum(II) complexes as well as for platinum(IV) prodrugs.



01

Monday Sept 19th
Auditorium Astier 11h



Ingo Ott (Technische Universität Braunschweig, Germany)

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On the Medicinal Chemistry of N-Heterocyclic Carbene Metal Complexes

Abstract. Organometallics with N-heterocyclic carbene (NHC) ligands are widely used in chemistry because of their catalytic properties. The increasing application of this type of organometallics has also triggered a steadily rising number of studies in the field of medicinal chemistry. In fact it has been demonstrated that metal NHC complexes can be used to develop highly efficient metallodrugs with possible applications in the treatment of cancer or infectious diseases. In this presentation our recent results on the biomedical properties of gold(I) and rhodium(I) based metal NHC complexes will be summarised.

02

Monday Sept 26th
Auditorium Astier 11h

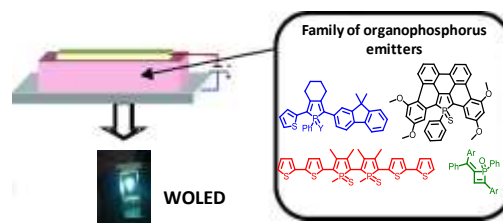


Muriel Hissler (ISCR, Université de Rennes 1)

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Advances in Phosphorus based Molecular Materials

Abstract. π -Conjugated oligomers and polymers based on heterocyclopentadienes have attracted strong interest in recent years owing to their potential applications for electronic devices. Their properties depend on the energy gap (E_g) which is affected by different factors involving planarity, aromaticity, and electronic nature of the substituents... With the challenge to control the energy gap, we have shown that the phosphole and phosphete rings are appealing building blocks for the construction of extended π -conjugated systems. The unique physical properties of these π -systems make them valuable building blocks for the development of dopant for white OLEDs in a complementary color approach.



03

October

Monday October 3rd
 Auditorium Astier 11h



Karine Philippot (LCC-CNRS, Toulouse)

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Synthesis of metal nanoparticles inspired by molecular chemistry concepts and their application in catalysis

Abstract. Concepts from molecular chemistry are useful to develop efficient synthetic tools in nanochemistry to achieve very small and well-defined metal nanoparticles.¹ A careful choice of the metal-organic complex and stabilizing agent used as precursors allows tuning the characteristics and surface properties of the particles that are among main points to control for any target application. Colloidal suspensions (in organic and aqueous environments) or supported systems of nanoparticles of various metals can be obtained. Selected examples will be presented as well as their interest in catalysis.²

1- Controlled metal nanostructures: Fertile ground for coordination chemists, C. Amiens, D. Ciuculescu-Pradines, K. Philippot, *Coord. Chem. Rev.* **2016**, *38*, 409-432.

2- On the use of Organometallic Concepts for the Synthesis of Nanocatalysts, T. Ayvali, K. Philippot, *New Materials for Catalytic Applications*, E. Kemnitz and V. Parvulescu (Eds.), Elsevier, 2016, Chapter 3, 41-79.

04

Monday October 10th
 Auditorium Astier 11h



Yves Blériot (Université de Poitiers)

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<http://glyco.labo.univ-poitiers.fr/>

Merging carbohydrate and superacid chemistries to explore glycosyl transfer

Abstract. The central reaction in glycosciences is arguably glycosylation, the formation of the glycosidic bond that connects a sugar motif to another molecule. It can be performed enzymatically through the use of glycosyl transferases or chemically using glycosyl donors and acceptors. Surprisingly, while the enzymatic mechanism has gained a high level of knowledge and sophistication, some of the details of the chemical glycosylation mechanism are still poorly understood.¹ Both mechanisms probably involve transient glycosyl cations to some degree. Observation, characterisation and further exploitation of these key ionic species could have a strong impact on applied and fundamental aspects of glycosciences. Our recent contribution to this field will be presented.²

1- L. Bohé, D. Crich, *C.R. Chimie* **2011**, *14*, 3-16.

2- A. Martin, A. Arda, J. Désiré, N. Probst, A. Mingot, P. Sinaÿ, J. Jimenez-Barbero, S. Thibaudeau, Y. Blériot, *Nat. Chem.* **2016**, *8*, 186-191.

05

Monday October 17th
Auditorium Astier 11h



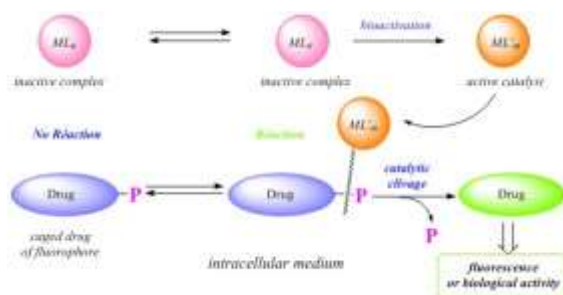
Olivier Riant (Université catholique de Louvain, Belgique)

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Catalyse organométallique bio-orthogonale en système biologique

Abstract. Le développement de réactions de catalyse par les métaux de transition dans les systèmes biologiques est un domaine émergent et encore peu exploré, et qui offre un terrain de jeux fascinant aux interfaces de la chimie et de la biologie. Notre groupe s'est récemment intéressé à cette problématique et les premiers résultats sur deux projets de catalyse in-cellulo seront présentés.

Notre approche est centrée sur la conception de nouveaux systèmes pré-catalytiques pouvant être activés, après internalisation dans une cellule tumorale, par un agent biologique. Nous avons trouvé deux familles de pré-catalyseurs basés sur l'Iridium et le Palladium activables par un cofacteur biologique. Ces catalyseurs ont été employés dans des réactions de réduction de double-liaisons carbone-hétéroatomes et en substitution allylique. Dans le cas des complexes de palladium, le mécanisme d'activation est dépendant de la concentration d'oxygène dans le milieu et une sélectivité en faveur des cellules hypoxiques a pu être quantifiée. Ces catalyseurs ont été appliqués à l'activation catalytique d'une molécule cytotoxique in-cellulo et pourrait ouvrir une nouvelle voie pour viser les tumeurs hypoxiques.



06

Monday October 24th
Auditorium Astier 11h

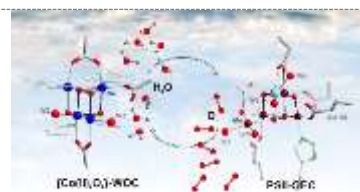


Greta R. Patzke (University of Zurich, Switzerland)

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Water Oxidation Catalysts for Artificial Photosynthesis: Bio-inspired vs. Solid State Design Pathways

Abstract. The development of efficient water oxidation catalysts (WOCs) is a crucial bottleneck on the way to the implementation of artificial photosynthesis as an elegant pathway to directly convert inexhaustible solar resources into chemical fuels. The worldwide quest for WOCs is both inspired by bio-inspired concepts and robust solid state approaches, and our research on cobalt-based WOCs aims to unify these strategies through targeted construction and mechanistic studies. Nature's {CaMn₄O₅} cluster of photosystem II remains a powerful molecular paradigm, and we have translated some of its key features into {Co(II)₄O₄} and {Co(II)₃LnO₄} cubane-type WOCs, which will be discussed in detail. These studies are complemented by explorations into spinel-type and perovskite-based WOCs, such as La_{1-x}Sr_xBO₃ perovskites (B = Co, Fe, Ni, or Mn). Key design parameters (e.g. redox inert cations) and insights are discussed for both WOC classes.



07

November

Monday November 7th | Off

Monday November 14th
Auditorium Astier 11h

Geert-Jan Boons (Utrecht University, The Netherlands)

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A fully synthetic carbohydrate-based vaccine for cancer



Abstract. A common feature of oncogenic transformed cells is the over-expression of unusual oligosaccharides such as Globo-H, LewisY, Muc-1 and Tn. Numerous studies have shown that this abnormal glycosylation can promote metastasis and hence its expression is strongly correlated with poor survival rates of cancer patients. Several elegant studies have exploited the differential expression of tumor-associated carbohydrates for the development of cancer vaccines. Unfortunately, in a number of clinical trials, tumor associated carbohydrate-protein conjugates elicited mainly inferior IgM antibodies. To address this problem, we have chemically synthesized and immunologically evaluated a number of fully synthetic anti-cancer vaccine candidates that constitute the minimal structural features required for effective immune activation. It was found that an appropriately glycosylated MUC1 peptide covalently linked to a promiscuous helper T-epitope and a Toll-like receptor (TLR) agonist can elicit robust *humoral* and *cellular immune responses* and was efficacious in reversing tolerance and generating a therapeutic response in a mouse model of mammary cancer.

Monday November 21st
Auditorium Astier 11h

Radovan Sebesta (Comenius University in Bratislava, Slovakia)

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Asymmetric catalysis using ferrocene catalysts and organocatalysts



Abstract. The lecture will focus on stereoselective domino reactions with organometallics, organocatalytic synthesis of pharmaceutical compounds, and synthesis of chiral ferrocenes. Stereoselective domino reactions using activated alkenes and naked carbenium ions in the Cu-catalyzed 1,4-additions of organometallic reagents will be presented. Then I shall deal with organocatalytic syntheses of oseltamivir, pregabalin, baclofen, and α,β -diamino acids. Last part treats stereoselectivity in the synthesis of ligand Taniaphos and diastereoselective retro-Brook rearrangement.

Monday November 28th
Auditorium Astier 11h



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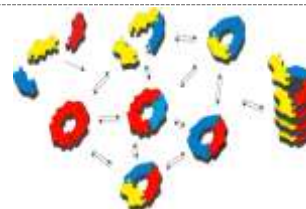
Sijbren Otto (University of Groningen, The Netherlands)

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Can we make life in the lab?

Emergence and evolution of self-replicating molecules from dynamic molecular networks

Abstract. How the immense complexity of living organisms has arisen is one of the most intriguing questions in contemporary science. We have started to explore experimentally how organization and function can emerge from complex molecular networks in aqueous solution. We focus on networks of molecules that can interconvert, to give mixtures that can change their composition in response to external or internal stimuli. Molecular recognition between molecules in such mixtures leads to their mutual stabilization, which drives the synthesis of more of the privileged structures (self-replication; see Figure). When such systems are operated under far-from-equilibrium flow conditions adaptation of the replicators to a changing environment can occur. Thus, the essential characteristics of Darwinian evolution of purely synthetic molecules are present and the prospect of synthesizing life de-novo is becoming increasingly realistic.



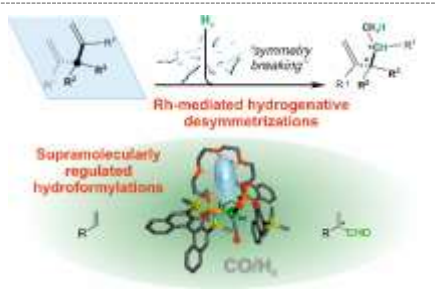
December

Monday December 5th
Auditorium Astier 11h



Anton Vidal (Institute of Chemical Research of Catalonia, Tarragona)
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Efficient ligand platforms from our group for enantioselective catalysis

Abstract. Our research interests encompass the design of efficient enantioselective catalysts for transformations of interest, and the study of their use to prepare enantiomerically enriched products of biological, or pharmaceutical relevance. Crucial aspects of this work include modular design of the catalysts; use of versatile synthetic procedures (organic and inorganic transformations, or supramolecular processes); incorporation of regulation mechanisms for their active-site geometry; and computational study of their catalytic cycles (through collaborations). The application of our ligands in new asymmetric hydrogenative transformations and hydroformylation reactions will be discussed (see above).



11

Monday December 12th
Auditorium Herpin 11h



Jesus Ferrando-Soria (ICMol, University of Valencia)
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Post-Synthetic Methods on MOFs: Chemical Reactors for Advanced Materials

Abstract. My present work aims at making a breakthrough step-change on the use of metal-organic frameworks (MOFs) as nano-reactors. Our synthetic strategy is based on the design of MOFs with tailor-made functional channels used as chemical reactors and solid-state post-synthetic methods. Using this approach, we show that novel species can be inserted or synthesized within the MOFs pores. In this talk, I will show unprecedented examples of ultra-small sized metal nanoclusters of application in catalysis synthesized within the pores of different MOFs as well as the insertion of functional molecules within a magnetic MOF.

12

January

Monday Jan 9th
Auditorium Astier 11h



Abderrahmane AMGOUNE (Toulouse University, LHFA UMR 5069)
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Design and Reactivity of Gold(III) complexes: Towards New Opportunities in Gold Catalysis

Abstract. In most gold catalyzed processes developed to date, gold(I) is used as a simple Lewis acid for electrophilic activation of π -CC bonds. This represents a severe restriction synthetically, and in this respect, gold is well behind the other transition metals that are known to promote a much greater variety of transformations. Gold is even considered to be incapable of promoting the important elementary steps in transition metal catalysis, *ie* migratory insertion and oxidative addition. Thanks to a rational ligand design approach, we recently showed that the reactivity of gold is much broader than anticipated. In this presentation, the design, structure and reactivity of new gold(III) complexes and their potential in cross coupling and insertion reactions will be discussed.

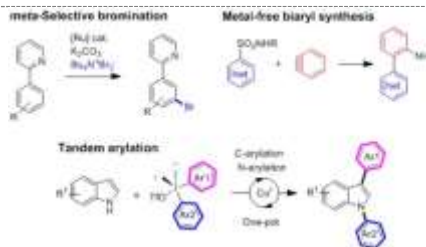
13

Monday Jan 16th
Auditorium Astier 11h



Michael F. Greaney (University of Manchester, UK)
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New Catalytic Chemistry for Heterocycle Synthesis

Abstract. Transition metal (TM) catalysts can control a vast range of chemical reactivity. At one extreme, they can harness and modulate the most energetic reactive intermediates, such as arynes and carbenes. Contrastingly, they can be used to activate inert, unreactive functional groups such as C-H bonds. Both of these areas offer tremendous potential for the discovery of new, catalytic reaction pathways for C-C and C-X bond construction. Focusing on the heterocyclic field, the talk will describe our progress in designing new TM-catalysed reaction systems and their application to modular heterocycle synthesis.



14

Monday Jan 23rd
Auditorium Astier 11h



15

Cyrille Train (Université Grenoble-Alpes)

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Une réponse radicale à quelques défis du magnétisme moléculaire

Abstract. Le magnétisme des objets moléculaires s'appuie sur la présence d'entités paramagnétiques. Historiquement, les ions métalliques ont pris le pas sur les radicaux organiques notamment en raison des impératifs de stabilité. Cependant, les radicaux organiques sont susceptibles d'assurer de fortes interactions d'échange. Utiliser des radicaux comme ligands pour développer des architectures discrètes ou étendues à propriétés magnétiques remarquables est donc une voie qui continue d'être explorée avec des radicaux classiques mais également à l'aide de nouveaux radicaux stables.

Monday Jan 30th
Auditorium Astier 11h



16

Masashi Okubo (The University of Tokyo, Japon)

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Materials Exploration for Advanced Batteries

Abstract. Limited performance of lithium-ion batteries forces us to develop advanced batteries. However, the presently-considered electrode materials are ion intercalation (carbon compounds, metal oxides and metal sulfides), alloying (phosphorus and tin) or conversion materials (metal oxides and metal sulfides), the energy and power densities of which are not satisfactory if the advanced batteries are to outperform the state-of-the-art Li-ion batteries. Hence, exploration for novel electrode materials is highly desired. In this seminar, I will demonstrate latent promises of various inorganic materials as the battery electrodes. The target materials include coordination compounds, metal oxides, and carbides.

[1] B. Mortemard de Boisse, *et al.*, M. Okubo, & A. Yamada, *Nature Commun.* (2016) 7, 11397. [2] S. Kajiyama, *et al.*, M. Okubo, & A. Yamada, *ACS Nano* (2016) 10, 3334. [3] X. Wang, *et al.*, M. Okubo, & A. Yamada, *Nature Commun.* (2015) 6, 6544. [4] X. Wang, *et al.*, M. Okubo, & A. Yamada, *Chem. Eur. J.* (2015) 21, 1096. [5] M. Okubo, *et al.*, *Chem. Commun.* (2014) 50, 1353. [6] D. Asakura, *et al.*, M. Okubo, & D. R. Talham, *J. Am. Chem. Soc.* (2013) 135, 2793.

February

Monday February 6th
Auditorium Astier 11h



17

Steve Goldup (University of Southampton, UK)

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Small, Functional Rotaxanes

Abstract. Our group have pioneered the use of “small” macrocycles in active template reactions in order to allow the synthesis of small(er), functionalised rotaxanes in excellent yield. I will describe some of our recent applications of this methodology to the synthesis of complex homo- and hetero-circuit [n]rotaxanes, as well as functional interlocked molecules including sensors and catalysts, and discuss our pioneering work on mechanically chiral rotaxanes, a previously hard to access class of chiral molecules.

Monday February 13th
Auditorium Astier 11h



18

Olivier Pluchery (INSP, UPMC)

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Molécules et nanoparticules d'or sur silicium : contrôler la morphologie du matériau et le fonctionnaliser pour l'électronique moléculaire

Abstract. Le silicium est un matériau fort de 60 ans au service de l'électronique. Il affiche des promesses renouvelées dans le domaine du photovoltaïque, de l'électronique moléculaire, et le développement de composants toujours plus petits qui faciliteront la transition de la micro- vers la nano-électronique. Dans mon exposé je détaillerai nos travaux de **fonctionnalisation moléculaire** du silicium et nos études des propriétés électroniques de ces couches. Grâce à des nanoparticules d'or jouant le rôle de « nano-réservoirs » à électrons, nous contrôlons le courant électrique, à l'électron près (blocage de Coulomb).

Monday February 20th
Auditorium Astier 11h



19

Cédric Fischmeister (CNRS-Université de Rennes 1)

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Homogeneous catalysis for the transformation of renewables

Abstract. The transformation of renewable and bio-sourced compounds is a major challenge for present and future chemical research. In this context, catalytic processes will play a major role to ensure efficient transformations with reduced environmental impacts. Our results on the implementation of olefin metathesis for the synthesis of bio-sourced polymer precursors and fine chemicals as well as recent developments on the transformation of oxygenated platform chemicals will be presented.

Monday February 27th
Auditorium Astier 11h



Thibaud Coradin (LCMCP, UPMC)

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Biomaterials : materials chemistry in a medical context

Abstract. The development of biomaterials requires the convergence of multiple expertises at the service of medicine. Chemistry plays a key role in imagining and constructing objects that will induce the adequate response of the body. However, combining functionality and biocompatibility remains a great challenge, as it implies a control of chemical and biological reactivity at multiple dimensional and time scales. Here we will illustrate some current approaches in materials chemistry applied to biomaterial design based on recent projects of the Materials & Biology group of LCMCP, especially in the area of skin wound healing.

20

March

Monday March 6th
Auditorium Astier 11h



Peter Faller (Institut de Chimie de Strasbourg, Univ. de Strasbourg)

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Copper(I/II) complexes with the peptide amyloid- β : structure, reactivity and biological relevance

Abstract. Copper is an essential element and is needed for several essential purposes such as energy production. Copper ions are generally tightly bound at specific sites to proteins. Copper inappropriately bound, often called labile or loosely bound copper, can be a very good catalyst for the production of reactive oxygen species (ROS). Thus copper metabolism has to be tightly controlled. There is a multitude of studies reporting a connection between Alzheimer disease (AD) and copper metabolism. In AD, the peptide amyloid- β (A β) forms plaques, which contain a high amount of Cu ions. This Cu bound A β is thought to contribute to the production of ROS observed in AD. We are interested in the in vitro reactivity of ROS production by of Cu-A β and other biological relevant peptides. The seminar reports on the recent advancements in this field.

21

Monday March 13th
Auditorium Astier 11h



Richard A. J. O'Hair (The University of Melbourne, Australia)

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More than just an analytical method! Using Mass Spectrometry to Build Bridges between Gas and Solution Phase Metal Chemistry

Abstract. Mass spectrometry based techniques have been developed over the past 50 years to provide fundamental structural, mechanistic and energetic information about intermediates and reactions associated with metal mediated processes, including catalytic cycles [1]. Many early studies involved the reactions of bare monoatomic transition metal cations, which unfortunately gave rise to the perception that gas-phase studies had little or no relevance to synthetic chemists. With the advent of electrospray ionisation, and with an appreciation of the differences in "languages" of the gas-phase and solution-phase chemist [2], exciting opportunities to bridge the gas and solution phases have emerged, thereby allowing the discovery of new species, reactions and concepts. In this lecture I will describe our recent efforts at using mass spectrometry to bridge the gas and solution phases to: (1) direct the synthesis of metal clusters; (2) discover new metal catalysts; (3) invent new metal mediated reactions.

References:

[1] O'Hair, R. A. J., *Int. J. Mass Spectrom.*, **2015**, *377*, 121

[2] Agrawal, D.; Schröder, D., *Organometallics*, **2011**, *30*, 32

22

Monday March 20th
Auditorium Astier 11h



John A. Murphy (University of Strathclyde, Glasgow, United Kingdom)

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Recent Studies of Electron Transfer in Organic Chemistry

Abstract. Electron transfer reactions are of central importance in nature and in synthetic chemistry. This presentation will describe recent progress in our laboratories in developing new reactions that are mediated by electron transfer, as well as in probing the mechanism of electron transfer reactions.



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Monday March 27th
Auditorium Astier 11h

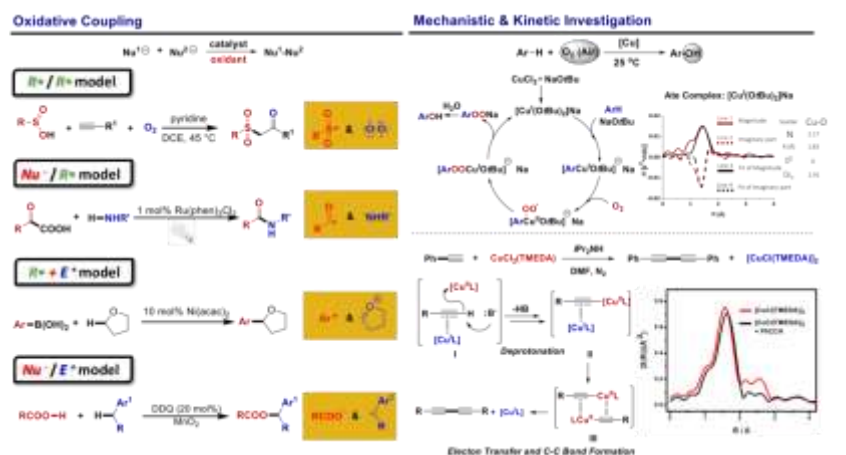


Aiwen Lei (IAS, Wuhan University, China)

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Radical C-H Activation/Radical-Radical Cross-Coupling

Abstract. Our research focuses on the oxidative coupling to develop a novel and efficient bond-formation method between two nucleophiles. We have successfully developed three generations of oxidative coupling. In addition, in-depth understanding toward the reactions is the other focus. Recently, a new series of oxidative coupling reactions have been developed. New insights into the reaction mechanism have also been revealed by operando X-ray absorption, Raman, electron paramagnetic resonance, and nuclear magnetic resonance spectroscopy.



24

April

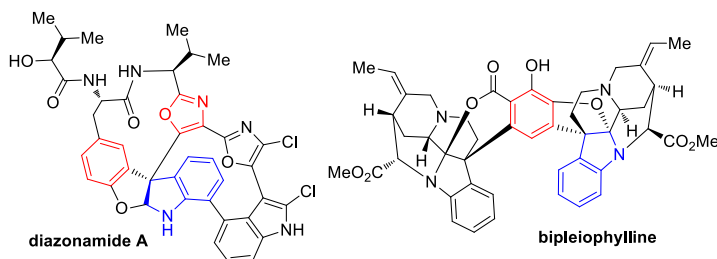
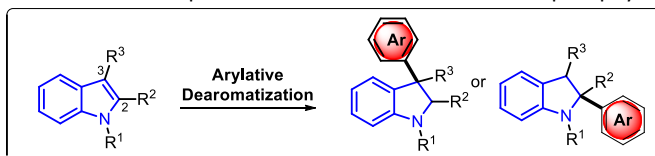
Monday April 24th
Auditorium Astier 11h

Guillaume Vincent (ICMMO, Université Paris Sud/Univ. Paris Saclay)

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Indoles Electrophiles et Désaromatization pour la Synthèse de Substances Naturelles

Abstract. The nucleophilicity of the indole nucleus at C3 is well established. In contrast the electrophilic character of indoles has been less studied but is a fascinating emerging topic. We are particularly interested in the generation of sp³ carbon centers through the reaction of the C2=C3 bond of indoles. We took advantage of the unusual electrophilic character of the indole nucleus to develop in the last years several methods to achieve the synthesis of arylated indolines related to natural products such as diazonamide A or bipleiophylline.



25

May

Monday May 15th
Auditorium **Durand** 11h



Rachel N Austin (Barnard College of Columbia University, USA)
rna2113@columbia.edu
C-O bond breaking and bond forming strategies: lessons from biology and heterogeneous biofuels catalysts

Abstract. Several mechanistic strategies for the selective catalytic addition and removal of oxygen atoms from organic molecules will be presented. An effort to find common themes in the high-valent iron strategies nature uses and the lower valent ruthenium-based approaches our lab has developed in a series of heterogeneous catalysts for biofuels upgrading will be discussed. Results from mechanistic work on alkane monooxygenase (AlkB), OleT and Ru and Ru/Ni TiO₂ catalysts will be described in this seminar.

26

Monday & Tuesday
May 22nd-23rd
Auditorium **Durand**

17^{ème} Journées de l'École Doctorale de Chimie Moléculaire (ED406)

Chris Moody
(University of Nottingham, RU)

Nathan D. McClenaghan
(Université de Bordeaux 1)

Miquel Costas
(Universitat de Girona, Espagne)

Frédéric Taran
(CEA Saclay)

Monday May 29th
Auditorium **Astier** 11h



David Bernier (Bayer CropScience, Lyon, France)
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From lab to field: selected cases from agrochemistry

Abstract. By 2050, the land area available for agriculture is expected to decrease significantly while the world population would grow from ~7 to over 9 billion people. Keeping access to quality food at an acceptable price will therefore constitute a considerable challenge. In this presentation, some examples of agrochemical innovation will be presented, from the discovery of a new active ingredient in a competitive landscape, to the challenges associated to searching for an up-scalable process. These examples will showcase several ways how chemists can contribute to agricultural innovation in the upcoming years.



27

June

Monday

June 19th

Auditorium Astier 11h

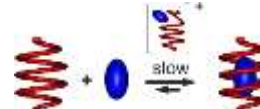
Yann Ferrand (CBMN, University of Bordeaux)

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Helical Foldamers: Highly Modular Scaffolds for Molecular Recognition



Abstract. Our group has developed helical foldamers – oligomers that adopt stable helical folded conformations – derived from aromatic amino acids. Some of these folded objects have shown unprecedented conformational stability even in water, and constitute convenient building blocks to elaborate synthetic, very large (protein-sized) folded architectures. Cavities can be designed within such synthetic molecules that enable them to act as artificial receptors for chiral polar guests. This design offers unmatched modularity in that each and every monomer may be varied in order to tune the structure, the dynamics and host-guest properties. Iterative evolution of oligoamide sequences was used to develop receptors able to bind a given guest with high affinity and selectivity. Rounds of selection have been made possible through the extensive use of crystallography, NMR and circular dichroism.



July

Lundi 3 Juillet

Auditorium Astier 11h

Prof. José R. Galán-Mascarós (ICIQ, Tarragona)

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Adventures in spin-crossover phenomena: from molecules with memory to multifunctional synergy



Abstract. Spin crossover (SC) compounds are bistable materials, where the magnetic state can be tuned from a low-spin configuration into a low-lying meta-stable high-spin configuration through external stimuli. The coordination chemistry of triazole (trz) ligands with Fe^{II} centers has delivered remarkable compounds, as those exhibiting memory effect over room temperature, with a wide thermal hysteresis (> 40 K). Here we will describe several chemical strategies to further exploit trz-based SC materials including complexes with thermal 100 K-wide hysteresis in the solid state; or multifunctional hybrid materials where the spin transition can trigger a synergic switching in the electrical properties.

xx
