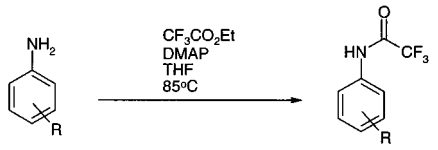
Organic Process Research & Development **2001**, *5*, 92–99

Highlights from the Literature

Some Items of Interest to Process R&D Chemists and Engineers as Selected by Trevor Laird and Stephen A. Hermitage

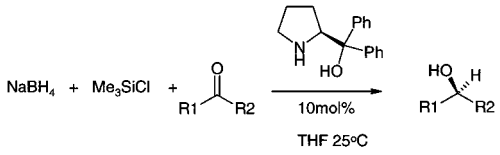
A convenient method for the selective 4-(dimethylamino)pyridine-catalysed trifluoroacetylation of anilines using commercially available ethyl trifluoroacetate has been described (*Tetrahedron Lett.* **2000**, *41*, 9957) by Prashad et al. from Novartis (Scheme 1). Anilines containing other functional groups (e.g., alcohols, phenols, hindered secondary amines, and secondary anilines) are also selectively trifluoroacetylated in high yields.

Scheme 1



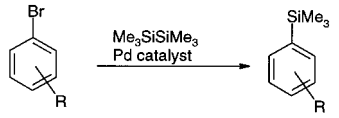
Jiang et al. from the Shanghai Institute of Organic Chemistry have reported (*Tetrahedron Lett.* **2000**, *41*, 10281) highly enantioselective reduction of prochiral ketones using a mixture of sodium borohydride, trimethylsilyl chloride, and (*S*)-α,α-diphenylpyrrolidinemethanol (Scheme 2). The optically active secondary alcohol products were obtained in excellent enantiomeric excess and almost quantitative chemical yield. The method compares favorably with the common "CBS reduction" and this in situ procedure eliminates the use of toxic borane complexes and the necessity of isolating unstable air and moisture sensitive B−H oxazaborolidines, providing a cost-effective and simple alternative.

Scheme 2



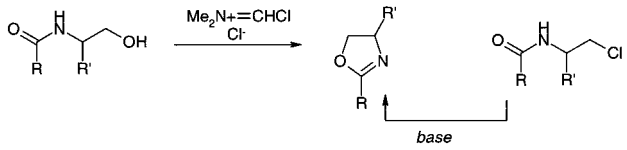
New catalyst systems for the catalytic silylation of aryl bromides have been described by Goossen and Ferwanah (*Synlett* **2000**, 1801). Their method (Scheme 3) uses two different sets of ligands and bases for electron-rich and electron-poor substrates and palladium catalysis with hexamethyldisilane. For electron-rich substrates, diphenyl-2′-pyridyl-phosphine in combination with K_2CO_3 gave the best results, whereas for electron-poor substrates, 2-(di-*tert*-butylphosphino)biphenyl/KF was preferred. Even base-sensitive aryl silanes, which are inaccessible by traditional routes via organolithium or organomagnesium chemistry can be prepared in a single step and in high yield.

Scheme 3



Wuts and co-workers have published (*J. Org. Chem.* **2000**, *65*, 9223) a method for the synthesis of oxazolines from amido alcohols using the low-cost Vilsmeier reagent. In their method (Scheme 4) some chloro analogue of the amido alcohol is produced, but this by-product may be cyclised to the oxazolines by treatment with DBU. Interestingly, the group describe that oxazolines may be reopened to the chlorides using pyridine hydrochloride.

Scheme 4



Organotin chemistry plays an important part in modern organic chemistry. However, one of the significant drawbacks of these methods is the removal and disposal of the excess reagents and organotin side products. Mascaretti et al. describe a practical method for the disposal of organotin residues from reaction mixtures (*J. Org. Chem.* **2000**, *65*, 9220). First the tin residues are separated from the reaction mixture by precipitation as Bu_3SnF using potassium fluoride. The organic tin fluoride is then treated with HCl/HNO_3 (1:1) followed by thioacetamide (an H_2S equivalent) to give insoluble SnS_2. Alternatively, other tin reagents may be treated with acid directly to give aqueous tin solutions which may then be treated with the thioacetamide.

Cooke and co-workers at GlaxoWellcome have described (*J. Org. Chem.* **2001**, *66*, 334) a novel and selective approach to enantiomerically pure bicyclic *trans*-lactams via a titanium enolate of a thiopyridyl ester. In their approach (Scheme 5) the lactam **7** is converted to the methyl ethers **6** before reaction with the titanium enolate of **5** to give the thioester **4**. Cyclisation of **4** using Cs_2CO_3 gave the translactam compound **3**. The latter compound was elaborated by coupling to the ene acid **2** to give the potent human neutrophil elastase inhibitor GW311616A, **1**.

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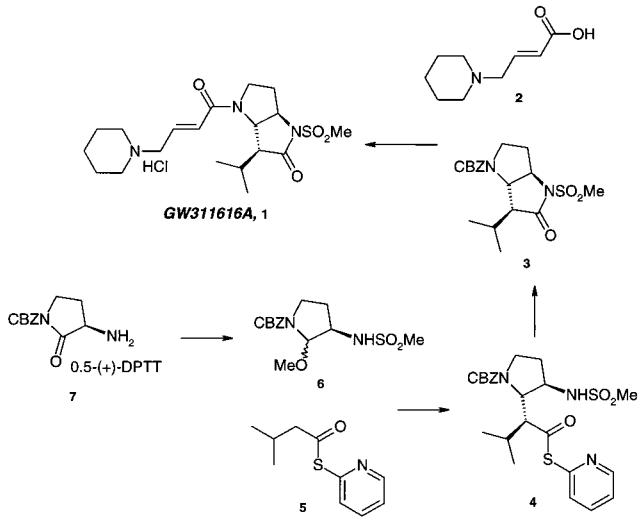
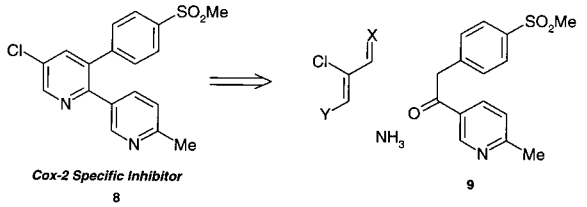
Scheme 5



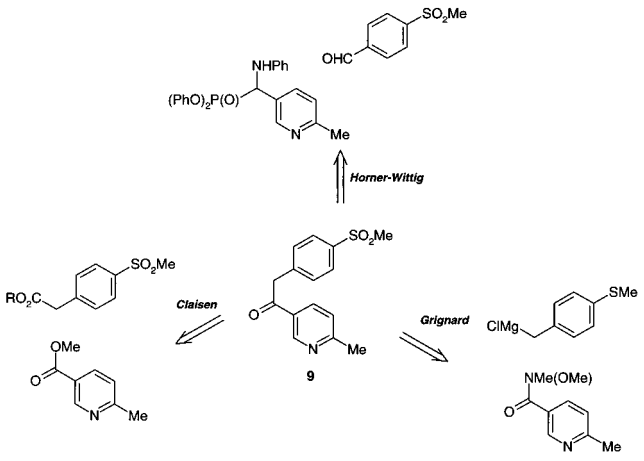
In previous Highlights we have followed the Merck story of vinamidinium salts. These salts have been used for the construction of COX-2 specific inhibitors (Scheme 6) by reaction with ketone **9** and ammonia. Recently Davies and co-workers from Merck have described (*J. Org. Chem.* **2000**, *65*, 8415) some of their synthetic approaches to the COX-2 inhibitor, **8**.

Scheme 6



Three of the approaches they discuss to the ketone **9** are outlined briefly in Scheme 7.

Scheme 7

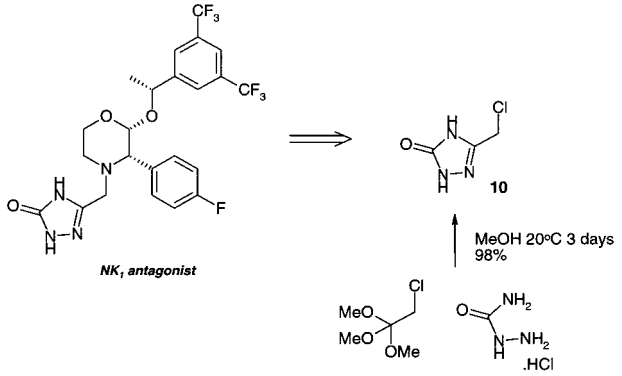


It is interesting that the chemistry described in the paper is classified by some of the "Great Names of Organic Chemistry", the likes of Horner, Wittig, Grignard, and Claisen. It highlights the importance of fundamental understanding of the great "old" reactions and the fact that these are the key building blocks that underpin the science of organic chemistry today! The paper goes on to describe the full development of the efficient practical annulation strategy adopted for the construction of the central pyridine ring.

For those following the vinamidinium salt chemistry a further paper has been published (*J. Org Chem.* **2001**, *66*, 251) in which their preparation and novel reduction chemistry is described.

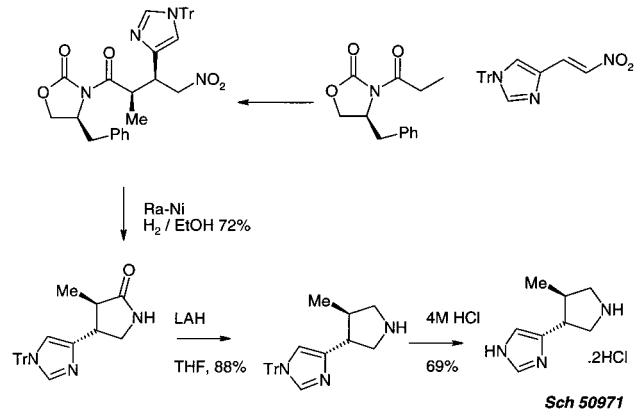
Retrosynthesis of the NK_1 antagonist (Scheme 8) gives the chlorotriazolinone **10** as a key building block. The process research group at Merck describe (*Tetrahedron Lett.* **2000**, *41*, 8661) its synthesis in a single step via the novel condensation of semicarbazide hydrochloride with an ortho ester. This is a great reaction to "push some arrows and draw a mechanism to" and highlights that complex molecules can be prepared in single steps from simple starting materials.

Scheme 8



A short asymmetric synthesis of the novel H_3 agonist Sch 50971 (Scheme 9) has been described by a group at Schering Plough (*Tetrahedron Asymmetry* **2000**, *11*, 3867). In their synthesis the key enantiodifferentiating step is the 1,4-addition of a chiral *N*-propionyloxazolidinone to a nitro olefin. The group screened a variety of conditions for this chemistry and achieved optimum selectivity using $TiCl_2(O^iPr)_2$ at 4 °C in CH_2Cl_2 with DIPEA as base to give a 16:1 ratio of diastereoisomers in 77% yield. The subsequent elaboration to drug substance is shown in Scheme 9.

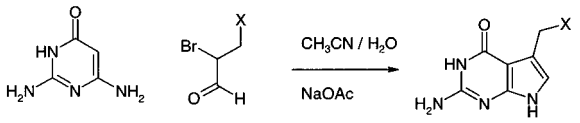
Scheme 9



The synthesis of pyrrolo[2,3-d]pyrimidines via cyclocondensation of β-alkoxy and β-amino-α-bromoaldehydes has been described (*Tetrahedron Lett.* **2000**, *41*, 9741) by Barnett

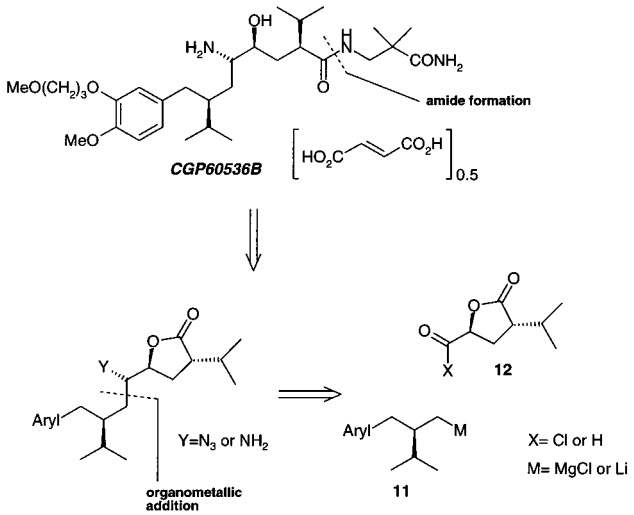
and Grubb from the Lilly research laboratories (Scheme 10). The choice of protecting group P (X = OP, or NRP, Scheme 10) proved critical to the success of the bromination and cyclocondensation reactions. A series of analogues where X = O, N were prepared by the group which may find application in the synthesis of other biologically active molecules.

Scheme 10

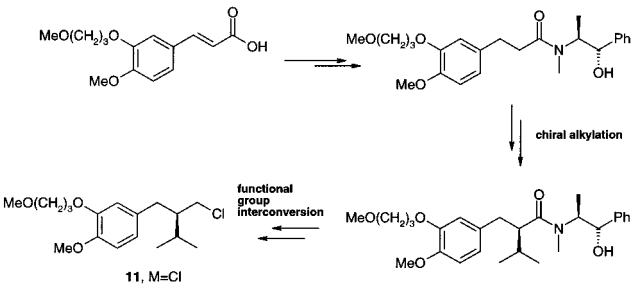


A convergent synthesis of the renin inhibitor CGP60536B (Scheme 11) has been described by Sandham et al. at Novartis (*Tetrahedron Lett.* **2000**, *41*, 10091). The retrosynthetic analysis is shown in Scheme 11 in which addition of an organometallic **11** into an electrophile **12** serves to set up a late-stage intermediate. In their synthesis pseudoephedrine serves as a dual purpose chiral auxiliary and protecting group in the preparation of the organometallic precursor (**11**, M = Cl) (Scheme 12) and electrophile **12** (Scheme 13).

Scheme 11



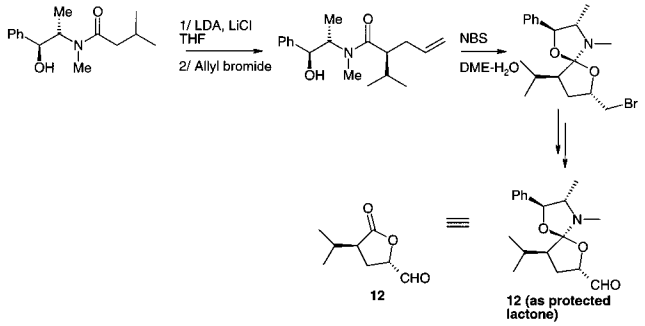
Scheme 12



Coupling of **11** and **12** via an organocerium reaction followed by functional group manipulations gave the renin inhibitor in >95% ee with chemistry amenable to scale up.

In an earlier Highlights, we commented on a one-step conversion of hydroxamic acids from carboxylic acids. An alternative approach using enzymes has also been recently published (Hacking, M. A. P. J et al. *Biotechnol. Bioeng.*

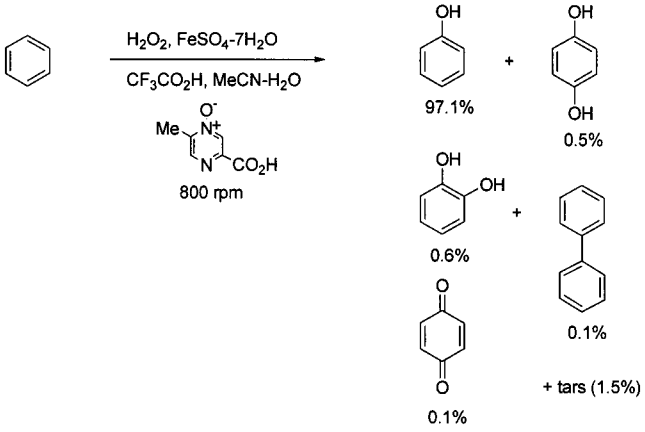
Scheme 13



2000, *68*, 84). Initial rates were highest in water, but overall productivity was optimal in dioxan; octanoic acid (250 g/L) could be converted into its hydroxamic acid (82% isolated yield) in 36 h with only 1% w/w *Candida antartica* lipase (NOVOZYME 435) in dioxan at 40 °C, using 50% aqueous hydroxylamine as reagent. This is a very simple and attractive methodology for scale up.

The direct oxidation of benzene and its derivatures to phenols would be an important industrial process if the selectivity could be controlled, but phenolic products usually oxidise further to give polyoxygenated products and tars. In biological systems this problem is overcome by segregating catalyst and product, and a recent publication uses this idea to improve the selectivity of oxidation of benzene to phenol by experimenting with two-phase oxidation systems. The choice of solvent/cosolvent for the benzene−hydrogen peroxide process is crucial, acetonitrile being the best when ferrous sulphate is the catalyst in the absence of ligands. When ligands and cocatalyst are optimised, a 97% selectivity is obtained. Since the catalyst resides in the aqueous layer, recycling is easy. The catalyst system shown in Scheme 14 below also oxidises alkanes.

Scheme 14

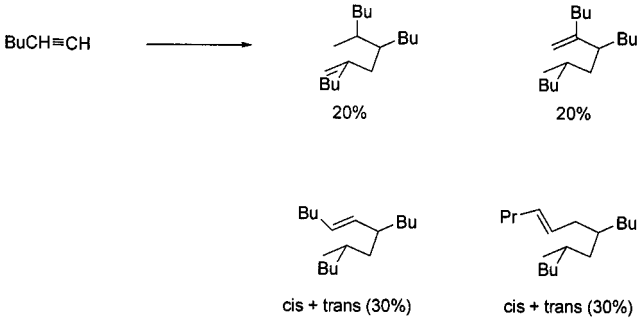


(Bianchi, D. et al. *Angew. Chem., Int. Ed.* **2000**, *39*, 4321.) This is an important paper, since previous attempts to oxidise benzene with Fenton reagents and the Gif system over the past 20−30 years have not been very successful. Interestingly, the authors do not comment on the potential reaction between acetonitrile and hydrogen peroxide to give peroxyimidates which may affect the process; propionitrile, however, was not an effective solvent. In solvents such as dioxan

and DMF, large amounts of overoxidised products ensued. The scientists, who are based at Enichem and Enitechnologie in Italy, are planning to develop a continuous process, more appropriate for large-scale production.

Chromium oxide−silica-based heterogeneous Phillips catalysts are used for manufacture of much of the high-density polyethylene (HDPE) used today. These catalysts can also selectively trimerise ethylene to 1-hexene, but it has now been found that, in contrast to other catalysts, these chromium compounds can catalyse trimerisation of other α-olefins under homogeneous conditions when complexed with triazacyclohexane (Kohn, R.D. et al. *Angew. Chem., Int. Ed.* **2000**, *39*, 4337). The resultant products are shown in Scheme 15.

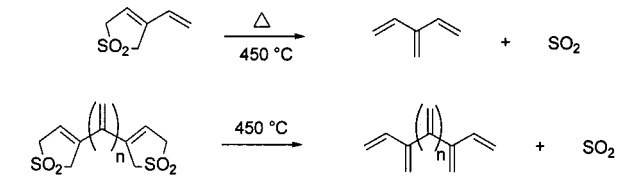
Scheme 15



Of all the simple molecules, the dendralenes have received least attention, partly because synthetic methods are generally low-yielding. A new approach to these highly unsaturated cross-conjugated molecules by cracking of sulpholenes should now make them more accessible (Sherburn, M. S. et al. *Angew. Chem., Int. Ed.* **2000**, *39*, 4331).

The molecules were stable enough at room temperature to obtain spectra and only polymerised slowly. The UV spectra indicate a nonplanar, nonconjugated arrangement of *(S)-trans*-1,3-butadiene and ethylene units in these molecules. We await publications on reactions of these fascinating molecules Scheme 16).

Scheme 16

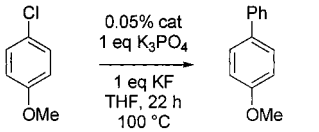


n = 0	85%
n = 1	65%
n = 2	52%
n = 3	64%

The importance of the Suzuki reaction in the synthesis of fine chemicals has been constantly emphasised in *Organic Process Research and Development*. Recent advances in the use of aryl chlorides to react with arylboronic acids have been described by the groups of Fu (*J. Am. Chem. Soc.* **2000**, *122*, 4020), Buchwald *(J. Am. Chem. Soc.* **1999**,*121*, 9550), Guram (*Tetrahedron Lett.* **1999**, *40*, 3855), Nolan (*J. Org. Chem*. **1999**, *64*, 3804), Herrmann (*J. Organomet. Chem.* **2000**, *595*, 186), and Beller (*Chem. Eur. J.* **2000**, *6*, 1830). In general, progress in this area has been by use of "in situ" Pd−L catalysts containing a Pd(II) source and sterically hindered basic ligands. Under these conditions the "in situ" catalysts are probably reduced under the reaction conditions to afford coordinatively unsaturated complexes such as 16e PdL_3, 14e PdL_2, and 12e PdL which may be the "real" catalysts.

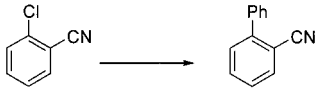
The latest report from Beller's group at Rostock (Andreu, M. G. et al. *Chem. Commun.* **2000**, 2475) uses various 1,6-diene palladium(0) monophosphine complexes which are more efficient than traditional Pd(II) PR_3 precatalysts. By fine-tuning the diene and the phosphine, the catalytic properties can be optimised (Scheme 17).

Scheme 17

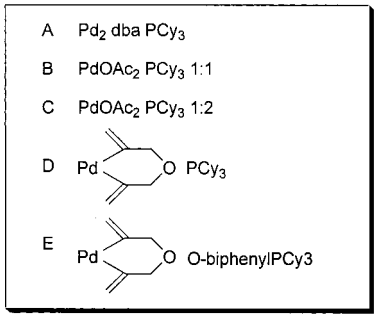


Catalyst	Yield	TON
A	5	100
B	8	160
C	28	560
D	56	1120
E	72	1440

A	8	160
B	11	220
C	28	560
D	79	1580
E	87	1740



A	91	1820
B	91	1820
C	95	1900
D	96	1920
E	97	1940

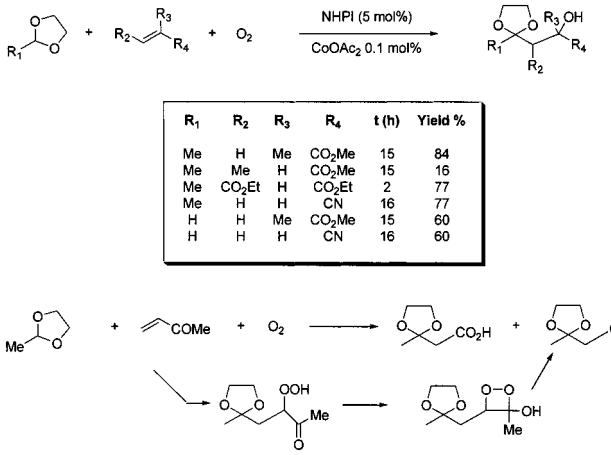


The rationale for the success is that by having a defined Pd monophosphine complex, decomposition reactions or side reactions prior to the formation of the "real" catalyst are avoided. This concept is useful for scale up, where the time-dependent formation of the "real" catalyst may lead to variations in yield and quality as the process is increased on-scale. It is clear that the order of addition of the constituents in the reaction may also have an effect.

The addition of aldehydes to terminal alkenes is a useful and atom-efficient process (for a review, see: Jun, C. H. et al. *Synlett* **1999**, 1), sometimes referred to as hydroacylation. A related process—hydroxyacylation—is much rarer but potentially just as useful. The radical addition of

1,3-dioxolanes to alkenes in the presence of oxygen is now reported by the group of Ishii in Japan (Hirano, K. et al. *Chem. Commun.* **2000**, 2457). Best results are using *N*-hydroxyphthalimide (NHPI) and cobalt(II) acetate. Interestingly, with methyl vinyl ketone, a mixture of the fragmented aldehyde and carboxylic acid is produced, probably via rearrangement of an intermediate hydroperoxide (Scheme 18).

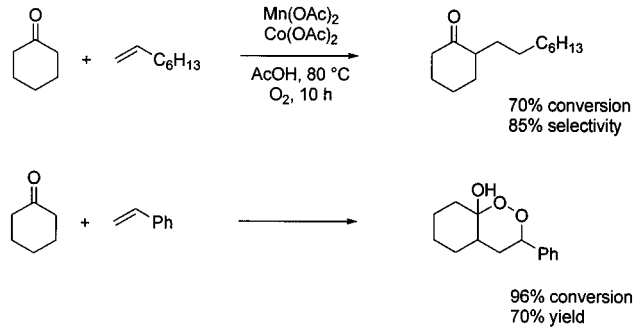
Scheme 18



R_1	R_2	R_3	R_4	t (h)	Yield %
Me	H	Me	CO_2Me	15	84
Me	Me	H	CO_2Me	15	16
Me	CO_2Et	H	CO_2Et	2	77
Me	H	H	CN	16	77
H	H	Me	CO_2Me	15	60
H	H	H	CN	16	60

The same group has also looked at the catalytic radical addition of ketones to alkenes (Iwahana, T. et al. *Chem. Commun.* **2000**, 2317)—see Scheme 19. The reaction works for cyclic and acyclic ketones with l-octene and isopropenyl acetate, but with styrene a cyclic peroxide is formed.

Scheme 19

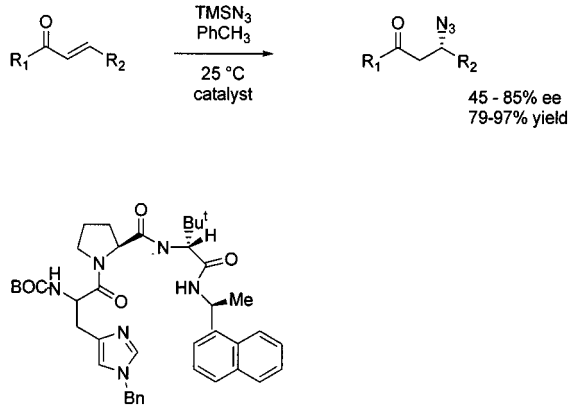


More examples of metal-free catalysis are being reported and small peptides and amino acids have found use in a variety of processes. A recent communication from the group of Miller at Boston College, U.S.A. demonstrates that unusual peptide-like molecules are effective in the asymmetric conjugate addition of azides to enoates (Hortsmann, T. E. et al. *Angew. Chem., Int. Ed.* **2000**, *39*, 3635) (Scheme 20).

Gold has, in part, been regarded as chemically inert but recent successes in homogeneous catalysis are changing our views. Tetrachloroauric acid on charcoal is the best catalyst for addition of hydrochloric acid to acetylene. A summary of recent progress in gold chemistry has recently appeared (Dyker, G. *Angew. Chem., Int. Ed.* **2000**, *39*, 4237).

The use of combinatorial techniques to discover and optimise chemical and biological catalysts is becoming

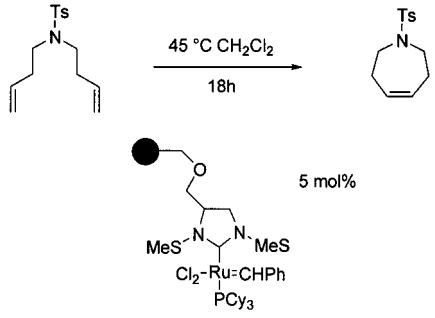
Scheme 20



widely used but suffers from the disadvantage that screening is less well advanced. IR thermography has emerged as a useful technique, and we have highlighted the work of Reetz and others in this area in the past. A group from Manchester, UK (Connolly, A. R. et al. *Angew. Chem., Int. Ed.* **2000**, *39*, 4268) have shown that a multiplexed array of thermistors can be used as an alternative to IR thermography for catalyst screening. The methodology was demonstrated in the enantioselective hydrolysis of terminal epoxides to diols using the cobalt−salen system.

Olefin metathesis continues to be a hot topic. A potential problem is separation of product from catalyst and recycling of the catalyst. The group of Blechert at Berlin have now synthesised an immobilised catalyst which gives good yields in a variety of metathesis processes (Schürer, S. C. et al. *Angew. Chem., Int. Ed.* **2000**, *39*, 3898). Examples using the polymer-bound catalyst are shown in Scheme 21. Product isolation is by simple filtration. Reuse of the catalyst is fine for a few cycles, but it loses activity in the long-term, leading to extended reaction times.

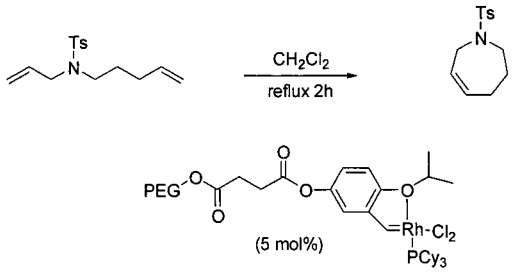
Scheme 21



In the previous paper, an alternative approach using a soluble polymer-bound ruthenium carbene complex is reported (Yao, Q. ibid. p 3896). The catalyst is precipitated from the reaction mixture and recycled—in this case, the recycling is successful as shown in Scheme 22 with only slight loss of activity after eight cycles.

The value of fine-tuning chemical processes is emphasised in an important paper from the group of Cainelli in Bologna, Italy (Cainelli, G. et al. *Chem. Commun*. **2000**, 2351) on temperature and solvent effects on enzyme stereoselectivity. In the reaction in Scheme 23, increasing the temperature

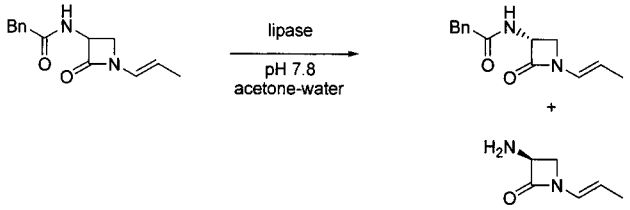
Scheme 22



Cycle	1	2	3	4	5	6	7	8
Conversion	98	97.5	96.5	95	95	93	93	92

initially lowered the selectivity to a minimum *E* value of 24 (at 28 °C), but if the temperature was further increased, the selectivity also increased to an *E* value of 130 at 55 °C. This phenomenon is ascribed to temperature-dependent substrate solvation and once again shows the importance of studying solvent and temperature effects in stereoselective reactions.

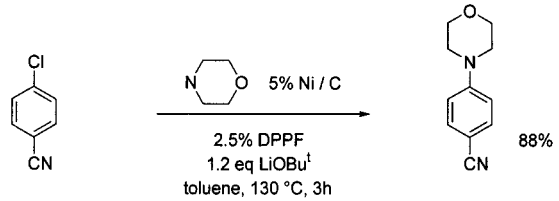
Scheme 23



Replacement of a leaving group on an aromatic ring by nitrogen has been the focus of much recent research, but all have relied on homogeneous catalysis. A heterogeneous process would be more useful to process chemists, and results using a nickel-on-charcoal catalyst have now been reported (Lipshutz, B. H. et al. *Angew. Chem., Int. Ed.* **2000**, *39*, 4492). The conditions are crucial, strongly refluxing solvent (dioxan or toluene but not THF) being required. Lithium *tert*-butoxide as base is much more effective than the sodium or potassium salts, and bases such as cesium carbonate were ineffective.

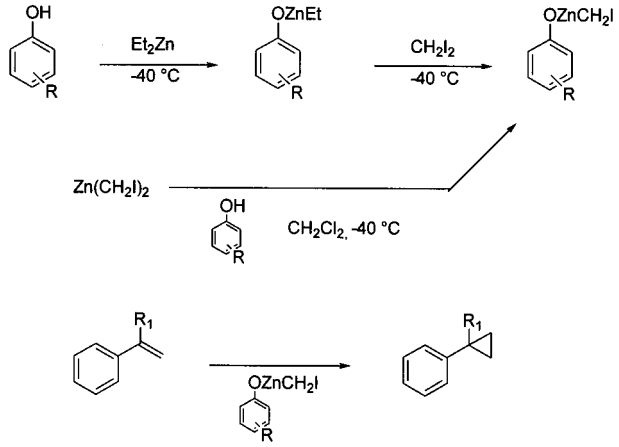
It was noted that there is a small loss of nickel from the catalyst, so this will contaminate either the product or the effluent—it may not, therefore, be suitable for the last synthetic step of pharmaceuticals. The use of Ni−C catalysts in the presence of Ph_3P for Negishi, Kumada, and Suzuki couplings has been reported by the same group (*J. Am. Chem. Soc*. **1999**, *121*, 5819; *Tetrahedron* **2000**, *56*, 2139) (Scheme 24).

Scheme 24



Iodomethylzinc phenoxides offer a useful alternative to traditional Simmons−Smith reagents. They are easy to make and highly reactive but have good stability. (Charette, A. B. et al. *Angew. Chem., Int. Ed.* **2000**, *39*, 4539). They are useful in the reaction with unactivated olefins (see Scheme 25).

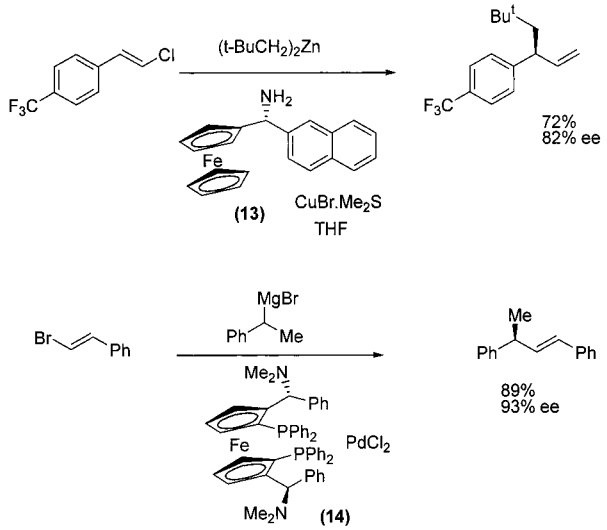
Scheme 25



Best results (yields > 95%) are achieved when the phenol has two ortho substituents and a para substituent (e.g., trihalophenols). Using chiral binaphthols, an asymmetric version is possible (33% ee).

A review on new applications of polyfunctional organometallic compounds—particularly organozincs—in organic synthesis has appeared from the group of Knochel at Munich (Boudier, A. et al. *Angew. Chem., Int. Ed*. **2000**, *39*, 4414). Their value in the synthesis of new chiral ferrocenyl ligands such as (**13**) and (**14**), useful in chiral alkylations is summarised along with a variety of other carbon−carbon bond-forming reactions in Scheme 26.

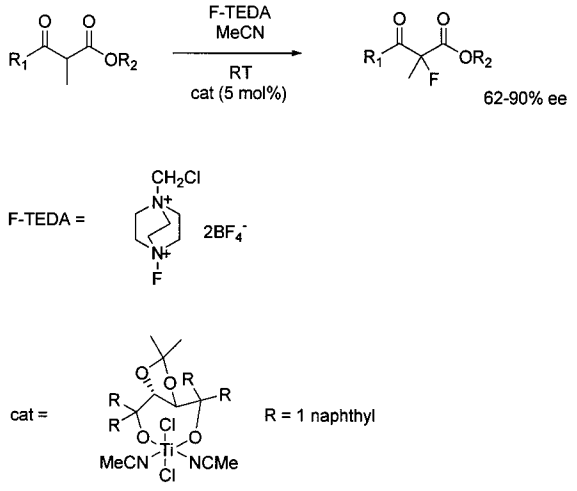
Scheme 26



Grignard reagents are often difficult to make from chloroaromatics, but transition metal catalysis may come to the rescue (Bogdanovic, B. et al. *Angew. Chem., Int. Ed.* **2000**, *39*, 4610). The magnesium is activated with ethyl bromide, $FeCl_2$, and $MgCl_2$ in THF before the organic chloride is added.

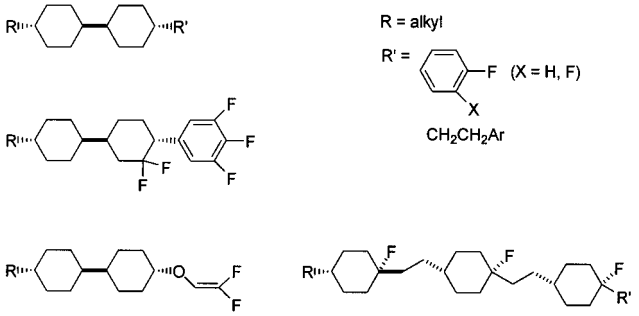
Asymmetric halogenation has always seemed to be an important goal that could be exploited industrially but few accounts of successful processes have been reported. This may change with impetus given by a report from the group of Togni at ETH, Zurich, on catalytic enantioselective fluorination of β-ketoesters (Hintermann, L. et al. *Angew. Chem., Int. Ed.* **2000**, *39*, 4359). The authors have previously examined asymmetric chlorination using *N*-chlorosuccinimide (*Helv. Chim. Acta.* **2000**, *83*, 2425) and point out that other asymmetric fluorine reactions such as epoxide-opening have also appeared (Bruns, S. et al. *J. Fluorine Chem.* **2000**, *104*, 247) (Scheme 27).

Scheme 27



The use of liquid-crystal displays in modern technological applications is increasing, and as demands on the technology grow, the structures of the materials become ever more complex (see example in Scheme 28). A review on the technology and the synthesis of liquid-crystal materials (Kirsch, P. et al. *Angew. Chem., Int. Ed.* **2000**, *39*, 4217) shows how important modern fluorochemistry is in this area; coupling reactions such as Suzuki methodologies are essential.

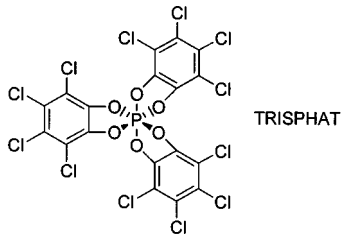
Scheme 28



A major problem with directed evolution, as a method to create enantioselective enzymes, is rapid measurement of product enantiomeric purity. Development of capillary array electrophoresis allows the determination of 7000 measurements per day, and the accuracy of the new methodology was checked against conventional (but slower) techniques (Reetz, M. T. et al. *Angew. Chem., Int. Ed.* **2000**, *39*, 3891).

Ee's can also now be measured by a mass spectrometric method (Tao, W. A. et al. *Chem. Commun*. **2000**, 2023).

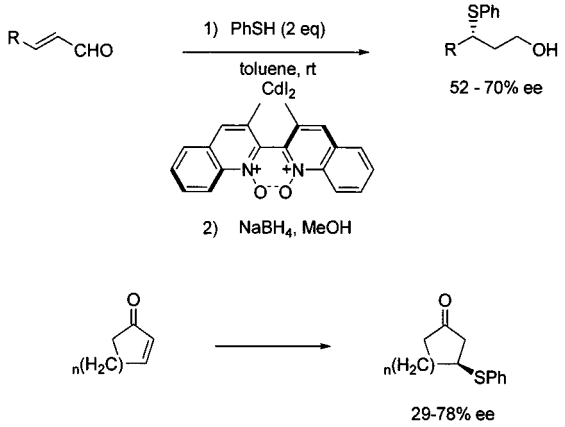
Enantioseparation by selective extraction is a potentially useful process which has only had limited use. A new method for easy separation of metal complexes (i.e., possible catalysts) uses the lipophilic TRISPHAT anions (**15**), previously used as a shift reagent in NMR. (Lacour, J. et al. *Angew. Chem., Int. Ed.* **2000**, *39*, 3695).



(15)

The enantioselective conjugate addition of thiols to enones is catalysed by chiral-*N*-oxide cadmium complexes (Saito, M. et al. *Chem. Commun.* **2000**, 1851), shown in Scheme 29.

Scheme 29



One of the major problems encountered in solid-phase synthesis, especially in the synthesis of oligosaccharides, is removal of benzyl-protection groups whilst the molecule is on the solid support—conventional catalysts do not work effectively without depositing palladium or other metals on the resin. Use of palladium nanoparticles yields useful results if a little slowly. (Kanie, O. et al. *Angew. Chem., Int. Ed.* **2000**, *39*, 4545).

A recent edition of *Chem. Eng. News* (January 1, 2001, p 21) contains an article by Michael Freemantle on ionic liquids, which seem to be "in vogue" these days. The focus is on the use of enzymes in these solvents, and the five-page article summarises publications in this area from the last few months. These include the synthesis of aspartame (Erbeldinger, M. et al. *Biotechnol. Prog.* **2000**, *2*, 4189) and conversion of nitriles to amides (previous paper and Lye, G. J. *Biotechnol. Bioeng*. **2000**, *69*, 227).

In the same article, reference is made to the use of ionic liquids for the Balz–Schiemann reaction (diazonium salts converted to aromatic fluorides). This reaction is carried out

industrially using HF and is reported to be a difficult reaction to scale—although fluorobenzene is, I think, made this way on a large scale. Perhaps the use of ionic liquids (Laali, K. R. et al. *J. Fluorine Chem.* ***2001****, 107*, 31), where quantitative yields are obtained and work up is simple, may yield the first industrial process using ionic liquids. As yet the price per kilogram for these solvents is high but as more uses are found, this will come down. The ease of recycle or reuse and simple product isolation are factors which are of increasing importance.

A more comprehensive review of the same topic, with emphasis on transition metal catalysis has appeared from the group of Wasserscheid at Aachen (*Angew. Chem., Int. Ed.* **2000**, *39*, 3772). This review gives excellent coverage of the catalysis literature which, unfortunately, many organic chemists do not read. The author has investigated processes for the dimerisation of 1-butene and has found that in ionic liquids, using a loop reactor, better selectivity, and catalyst turnover number are achieved compared to other organic solvents. He predicts the field opening up in the future and industrial processes resulting.

The same issue of *C&EN* (p 8) also reports that at the Pacifichem meeting in December, Professor Ryoji Noyori from Nagoya, Japan, reported the synthesis of a catalyst for the asymmetric reduction of ketones with a turnover number of 2,400,000 and a turnover frequency of 228,000 per hour.

The trend towards "process intensification" continues, and chemical engineers are innovatively pursuing new types of reactors, which can be used for continuous processing of fine chemicals. A group at the University of Newcastle, UK, have devised a spinning-disk reactor (Boodoo, K. V. K. et al. *Green Chem.* **2000**, *2*, 235) which is being used in this article for polyester condensation.

In previous issues, we have highlighted the dangers of working with perchlorate salts. Apparently, there are other problems with these anions—they have been found at levels of up to 3700 mg/L in ground- and surface waters in several U.S. states (California's provisional action level is only 18 μg/L). It is likely that most of this perchlorate comes from the defense and aerospace industries. It poses severe problems for remediation since typical water treatment technologies (ion-exchange, carbon absorption, air stripping) are ineffective. It has now been shown that simple rhenium complexes with 2-hydroxyphenyl-2-oxazoline are effective catalysts for the reduction of perchlorate to chloride using sulphides (Abu-Omar, M. M. et al. *Angew. Chem., Int. Ed.* **2000**, *39*, 4310).

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