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TEMPLATE CATALYSIS VIA NON-TRANSITION METAL COMPLEXES. NEW HIGHLY SELECTIVE SYNTHESES ON PHENOL SYSTEMS

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Abstract - A methodological approach to conventional phenol chemistry based on the concepts and achievements of modern coordination chemistry allowed to find specific conditions for improving classical reactions and discovering new selective processes.
Substrates, reagents, and ligands could be organized around non transition metal cations in suitable complexes, which were able to control the reactions and to determine highly selective ortho-attack on phenol systems.
Template reactions of phenol substrates with carbonyl compounds in the presence of suitable ligands led to new general processes of ortho-formylation, ortho-acylation, ortho-alkylation and allylation. A rational route to all-ortho regular novolac resins was also disclosed. By using the basic strategy of Ziegler-Natta catalysis, the first synthesis of isotactic and syndiotactic all-ortho ethylidene-linked polyphenols was performed.
Other synthetically useful Friedel-Crafts processes were performed according to an intramolecular template mechanism leading to new syntheses of important classes of oxygen heterocycles such as flavenes, chromanes, benzofuran derivatives, benzodioxins, and benzopyrylium salts.

STRATEGY

Activation of phenols, enols and indoles, which are typical ambident nucleophilic systems, is traditionally achieved by using strong bases which convert the substrates into the corresponding anions (phenolate, enolate, etc.), along with the use of dipolar aprotic solvents of high donicity (1) or phase transfer catalysis (2). In these conditions, the negative influence of the cation on reactivity is strongly reduced and, as a consequence, high activation of the substrate is usually observed. Moreover, predominant or exclusive functionalization at the more negative center (O, N) of the ambident system occurs (3).

Reversing this general synthetic strategy, some years ago we focused our attention on the possible positive role of the cation and looked at these reactions in terms of coordinated processes in self-organized systems rather than of anion activation only (4). As far as phenol chemistry is concerned, we studied the possibility to exploit the complex structures of phenol salts as self-catalyzing systems, thereby systematically changing their organization in order to control and diversify their reactivity. In this systems the cation can play a fundamental role in coordinating both the phenolic substrate and the reagent, inducing intramolecular irreversible reactions within the phenolate-reagent complex.

In order to achieve this goal the following rules are strictly required: i) the structure of the salt has to be designed according to the reagent or, viceversa, the reagent has to be selected in order to chelate the cation; ii) solvent and any species present in the reaction medium must not exclude the reagent from complexation in the reactive structure of the salt.

On these bases a systematic research on phenol salts of highly coordinating non-transition metals was undertaken, utilizing mainly salts of lithium, magnesium, zinc, titanium, etc., in aprotic non polar media.

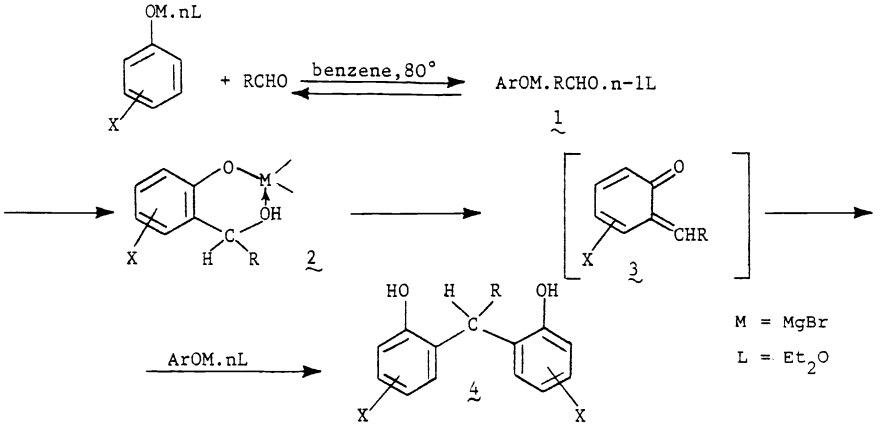
Initially we selected as reagents carbonyl compounds and their oxygen derivatives according to their known complexing ability towards the aforementioned hard cations.

TEMPLATE REACTIONS OF METAL PHENOXIDES WITH CARBONYL COMPOUNDS

General Features and Reaction Mechanism

In contrast to some data reported in the literature (5) and to the general reactivity modes formulated for salts of ambident anions(3), we found that aryloxymagnesium bromides react with orthoesters(6) and aliphatic and aromatic aldehydes or their acetals(4,7,8) in aprotic apolar media.

Scheme 1



The main features of these processes are the exceptionally high selectivity of the attack at the ambident phenoxide ion and the lack of polyalkylated products: a C-ortho-regiospecific reaction is always observed.

The exclusive preference of bond formation at the ortho-carbon of phenoxide anions is shown by the lack of reaction in the case of 2,6-disubstituted aryloxymagnesium halides.

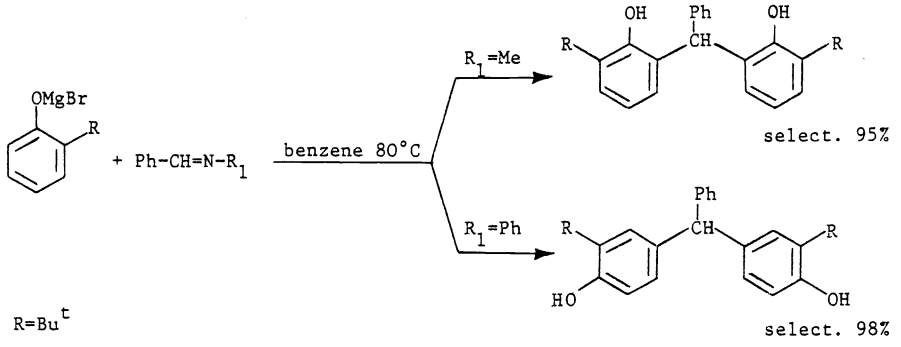
In all cases, electrondonating groups on the phenolic substrate and electronwithdrawing groups on the reagent favour the reaction according to the general features of electrophylic aromatic substitution (4,7).

The reaction pathway involves: a substrate-reagent complex 1, an o-hydroxybenzyl derivative 2, which eventually generates ortho-quinonemethide intermediates 3 via a coordinated process (9). This species selectively reacts with aryloxymagnesium bromides to give the final reaction products 4 (10) (Scheme 1). In certain cases the different stereochemistry (Z or E) of suitable ortho-quinonemethide intermediates can determine the reaction pathway(11).

The formation of complex 1, as key step in the reaction course, is supported both by direct and indirect evidence. Firstly, in all the cases investigated we observed positive results only with salts of higly coordinating cations whereas those of alkali metals (K^+, Na^+) did not react at all (4,7). Moreover, any chemical species, such as donor solvents, which compete with the reagent in complexing the reacting ion-pairs, depresses or inhibits the reaction (6,7). Furthermore, the presence in the substrate of groups (e.g. 2-OCH_3, 2-Cl, etc.), which give rise to internally chelated complexes, reduces the interaction between the cation and the reagent(7) and consequently inhibits the reactivity.

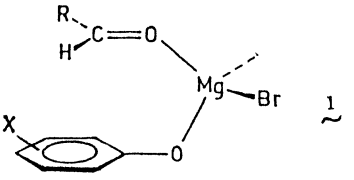
The sensitivity of these reactions to steric factors also agrees with the hypothesized coordinated mechanism. Thus, for example, in the reaction of aldimines with aryloxymagnesiun bromides(12) both reactivity and regioselectivity are dramatically influenced by the bulkiness of the substituent on nitrogen (Scheme 2). It is possible to move gradually from a selective ortho- to a para-attack thereby varying the steric requirements of substituents. Also the reactivity is affected and no reaction occurs with a very bulky group such as cyclohexyl.

Scheme 2



It is noteworthy that no mixed 2,4'-arylidene bisphenols are obtained. The regioselectivity of the overall process is determined by the first step which leads to the ortho or para Mannich base intermediates: both these compounds easily collapse to their corresponding quinonemethides. Evidently, only ortho-quinonemethides are able to form oriented complexes with the phenol salt which subsequently gives the all-ortho derivatives.

Scheme 3



However, the major evidence for the formation of oriented complexes **1** between aldehydes and aryloxymagnesium bromides is the upfield shift experienced by the formyl proton upon complexation in contrast with a "normal" downfield shift observed in complexes with other Lewis acids (BF_3, $MgBr_2$) in the same conditions (13). The data obtained show a 1:1 stoichiometry for these complexes and suggest a geometry (Scheme 3) in which the carbonyl and the phenol ortho-carbon are already oriented in the ground state in such a way that the subsequent "intracomplex" ortho-regioselective reaction can easily occur when this position is unsubstituted.

SYNTHETIC APPLICATIONS

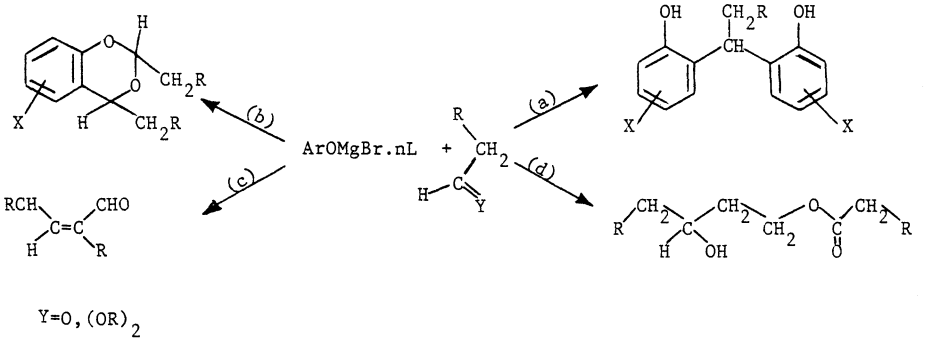
Reactions with Linear Aliphatic Aldehydes, Acetals and Orthoesters

In aprotic apolar media linear aliphatic aldehydes give rise to a large variety of competitive processes catalyzed by phenol salts. However, we succeeded in performing very highly selective processes by changing the nature of the reacting complexes.

The preparation of 2,2'-alkylidene bisphenols can be performed by using aryloxymagnesium bromides and the aldehyde acetals (Scheme 4, path a)(8).

The reaction carried out with titanium phenolates gives, at room temperature, 3H-1,3-benzodioxins (path b, 55-85% yield; ca. 90% selectivity) (14). On the other hand, the 2,4,6-trisubstituted magnesium phenolates are able to catalyze the aldehyde self-condensation in a process which is very sensitive to the nature of the ligand (Scheme 4, paths c and d; ca. 95% yield) (15).

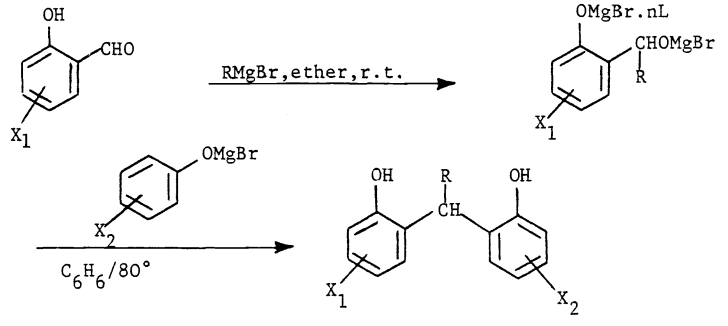
Scheme 4



Y=O, $(OR)_2$

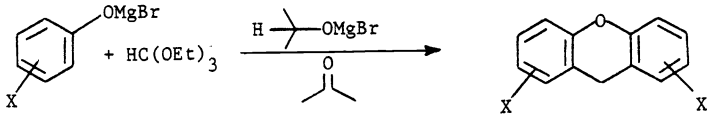
The hitherto unknown "unsymmetrical" bisphenols are obtained in a facile and selective synthesis(16) starting from salicylaldehydes according to Scheme 5.

Scheme 5



The reaction of aryloxymagnesium bromides with orthoformate gives rise to different products of ortho-attack depending upon the nature and the position of the substituents on the phenol ring. Salicylaldehydes, triarylmethanes, xanthilium salts, and ox-redox products are obtained from this reaction (6). A convenient synthesis of xanthene derivatives was developed (17) (Scheme 6) in a one-pot process in which selective ortho-attack at the phenol ring is coupled to a quantitative ox-redox process of the xanthilium intermediate.

Scheme 6

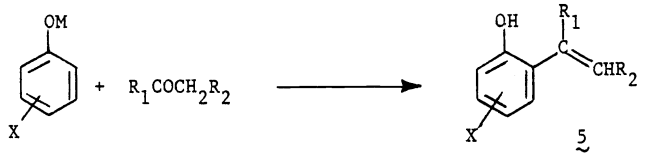


Reaction with Ketones: New General Synthesis of ortho-Vinylphenols

With ketones as reagents, the self-condensation process, which occurs in the presence of magnesium salts, could be successfully inhibited by the use of aluminum phenolates (18). In this case the intermolecular process to bisphenols is inhibited and the ortho-quinonemethide intermediate is converted into the corresponding 2-alkenylphenol 5 through an intramolecular keto-enol tautomerization(11). Ortho-vinylphenols can also be obtained from non enolizable derivatives of ketones and aryloxymagnesium bromides(19).

Again, the nature of the coordinating cation is the determining factor for the reaction selectivity.

Scheme 7



Reaction of PhOM with cyclohexanone (a).

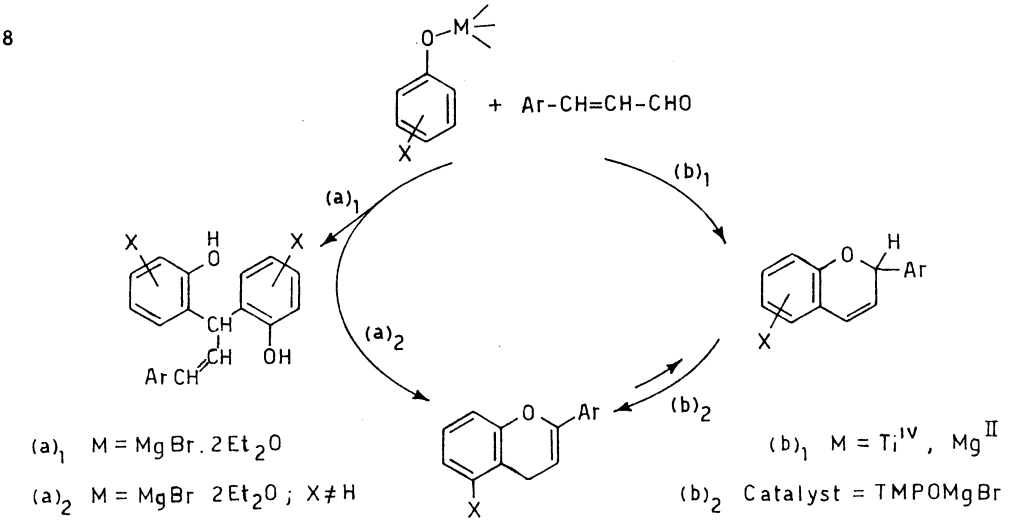
Metal	Recovered phenol	Yield(%)	Selectivity(%)
Al(III)	5	93	98
Ti(IV)	47	41	78
Sn(IV)	55	40	89
B(III)	77	18	78
Li(I),Na(I),K(I), MgBr(I)	96	-	-

(a) Yield and selectivity based on 2-cyclohexenyl phenol (g.l.c.).

Reaction with α,β-Unsaturated Carbonyl Compounds: New General Synthesis of Flavenes and Chromenes

We also succeeded in directing the reaction of metal phenolates with α,β-unsaturated

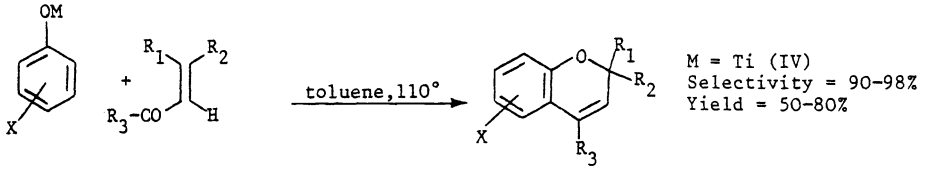
Scheme 8



carbonyl compounds towards synthetically useful pathways. Cinnamaldehydes react with aryloxymagnesium bromides to give the expected dimeric derivatives in high yields, except when a substituent is located near the position of the electrophilic attack, where flav-2-enes are mainly obtained. On the other hand we also succeded in obtaining flav-3-enes (95% selectivity) from a wide range of phenolic substrates by using titanium phenolates (20) (Scheme 8).

This methodological approach led us also to develop a general procedure for the synthesis of chrom-3-enes: indeed, precocene and analogous natural derivatives were prepared with a very simple and general procedure (20) (Scheme 9).

Scheme 9



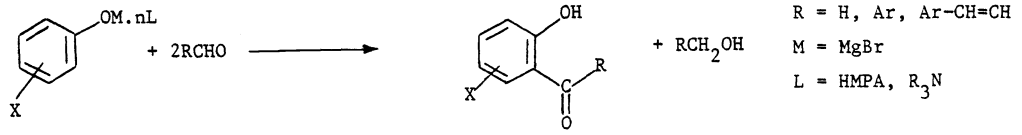
A selective control of α,β-unsaturated aldehyde self- and mixed condensations could be achieved with other carbonyl compounds (21).

Selective ortho-Formylation and Acylation of Phenols

In order to develop a general synthesis of salicylalcohols we tried to inhibit their conversion to ortho-quinonemethides, which is catalyzed by the acid counterions, using suitable basic ligands specific for magnesium and aluminum cations.

In benzene, aryloxymagnesium bromides complexed with stoichiometric amounts of HMPA, or R_3N are still able to coordinate formaldehyde, thus reacting ortho-regioselectively to give the salicylalcohol intermediate 2. Coordination of the basic ligand to the cation inhibits the second electrophilic attack but promotes a hydride shift from alcohol 2 to a second formaldehyde molecule giving salicylaldehydes in high yields (7).

Scheme 10



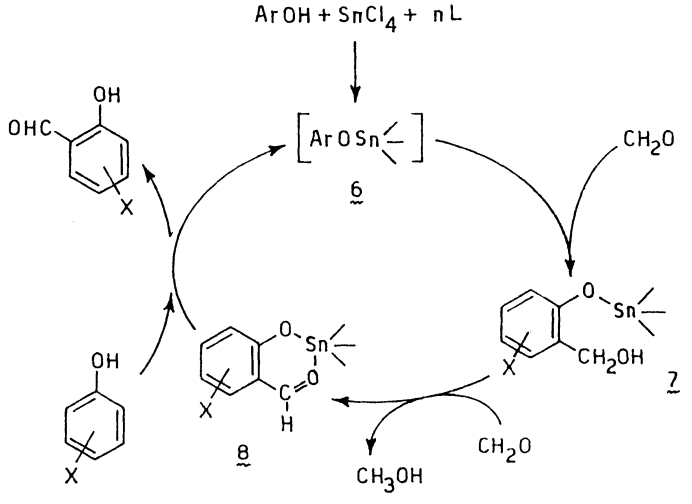
This new reaction seems to be quite general (Scheme 10) and could be extended to other non enolizable aldehydes, allowing us to perform the selective synthesis of 2-hydroxybenzophenones (22) and 2'-hydroxychalcones(23).

Owing to the importance of 2'-hydroxychalcones, as intermediates in the preparation of naturally occuring oxygen heterocycles, we think that this route may provide an efficient approach to many syntheses in the flavonoid area.

Catalytic Process for Salicylaldehyde Synthesis

So far, we have examined processes which are highly ortho-regioselective but which are stoichiometric respect to the metal used. However, in the case of the salicylaldehyde synthesis, we succeeded in making catalytic the process by using $SnCl_4$ complexed with a proper basic ligand (24). The postulated catalytic cycle is depicted in Scheme 11.

Scheme 11



Initially the phenol reacts with $SnCl_4$ to give the mixed species **6**, while the resulting hydrogen chloride is trapped by the amine. The interaction of species **6** with formaldehyde in an oriented complex similar to **1** leads to salicyl alcohols **7**.

Different amines explicate different activity supporting the hypothesis that their role is not confined to trapping the acid, which is generated in the exchange reaction, but also to act as specific ligands for the metal catalysts (Scheme 12).

Scheme 12. Influence of the ligand on the Lewis acid-catalyzed reaction between phenol and paraformaldehyde.

Run	Ligand	Yield (Selectivity) %
1	Me_3N	58 (84)
2	Bu_3N	59 (94)
3	Trioctylamine	78 (100)
4	Pyridine	40 (81)
5	Picoline	68 (90)
6	$P(Bu)_3$	28 (60)
7	Dimethoxyethane	15 (34)

The next stage involves a red-ox process leading to salicylaldehyde and methanol. On the basis of kinetic evidences and isotope labelling measurements, we concluded that this reaction involves a direct hydride-transfer from salicyl alcohol **7** to the coordinated carbonyl group *via* a concerted mechanism (25). Finally, an exchange reaction between the tin complex **8** and phenol probably restores the reacting species closing the cycle.

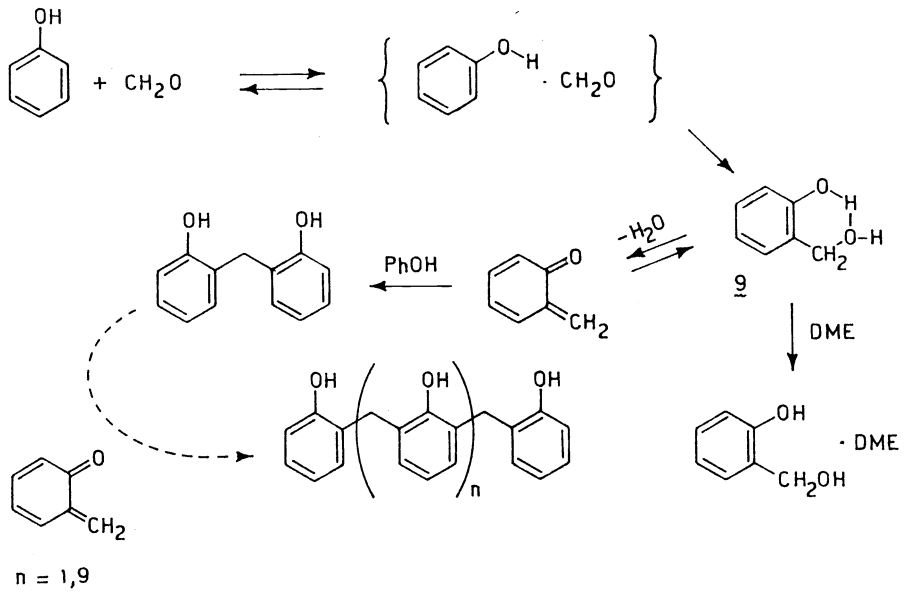
This process provides a widely applicable exclusive *ortho*-formylation of phenols with formaldehyde through an easily viable route and in most instances represents a marked improvement over the existing methods both for laboratory-scale preparations and for industrial applications (26).

Rational Synthesis of "All-*ortho*" Novolac Resins

The reaction of aryloxymagnesium bromides and formaldehyde in non polar solvents and in the absence of basic additives produces mainly 2,2'-dihydroxydiphenylmethanes (7) or higher homologues (27). The degree of polymerization can be easily controlled and linear *ortho,ortho'*-methylene bridged oligomers up to ten phenolic units were easily prepared and fully characterized (28).

However, conditions were found to obtain all-*ortho* novolac resins with exceptionally high selectivity and conversion either by the use of Lewis acid catalysts (28) or directly from phenols and formaldehyde (29) (Scheme 13).

Scheme 13



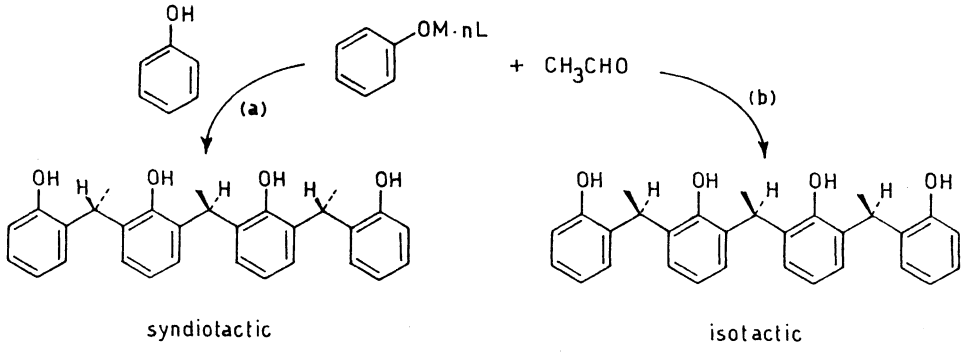
The last result is particularly remarkable since it shows that in suitable conditions also the proton can act as coordinating cation giving template processes, provided basic ligands are absent and the reaction is carried out at higher temperature (160-180°C). In this case it is possible to stabilize the salicyl alcohol intermediate **9** by interaction with a basic ligand, i.e. DME, thereby performing a simple selective synthesis of this derivative (30).

On the basis of the general principles outlined before, we have also reinvestigated the reaction between phenols and acetaldehyde or its diethyl acetal (Scheme 14). The best results are obtained by using aryloxymagnesium bromides whereas the uncatalyzed reaction occurs only sluggishly.

Evidently, the condensation products can have an isotactic and syndiotactic configuration: pure binuclear, trinuclear (meso and racemic), tetranuclear (isotactic and atactic) and pentanuclear (atactic) oligomers were isolated and fully characterized (31).

It is noteworthy that the reaction occurs with catalytic amounts of aryloxymagnesium bromides and the phenol/phenoxymagnesium bromide ratio seems to have a strong influence on the stereochemistry of the reaction (Scheme 14).

Scheme 14



(a) PhOH/PhOMgBr = 1:1 ; selectivity 85%

(b) PhOMgBr only ; selectivity 78%

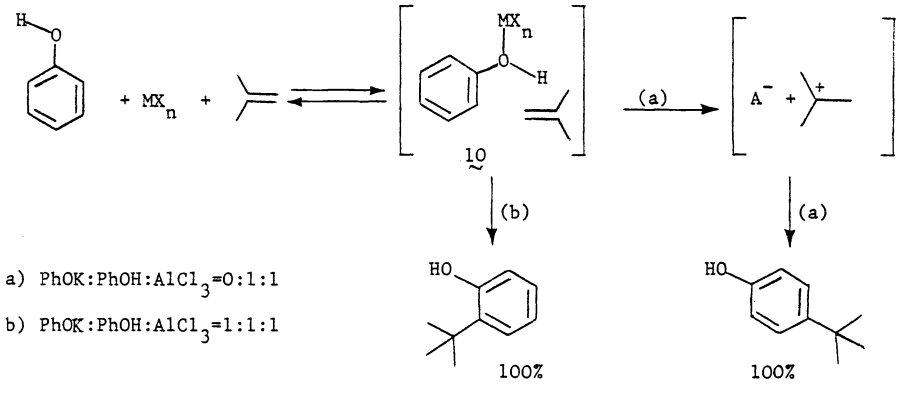
The high stereocontrol obtained in this reaction indicates the possibility to utilize the basic strategy of the classical olefin polymerization also in phenol-aldehyde polycondensation.

LEWIS-ACID TEMPLATE REACTIONS ON PHENOLS AND THEIR ALKALI SALTS

The previously evidenced possibility to modify hydrogen bonding or dipolar interactions by specific complexation of a Lewis acid with the phenolic hydroxyl prompted us to extend our research to the reactions of these systems with alkenes and alkynes.

The crucial point of this methodological approach is the possibility to enhance and control the acidity of the phenolic substrate (32) to generate donor-acceptor complexes with the desired reagent. The intramolecular collapse of this complex determines the subsequent reaction course giving ortho-selective processes (Scheme 15)

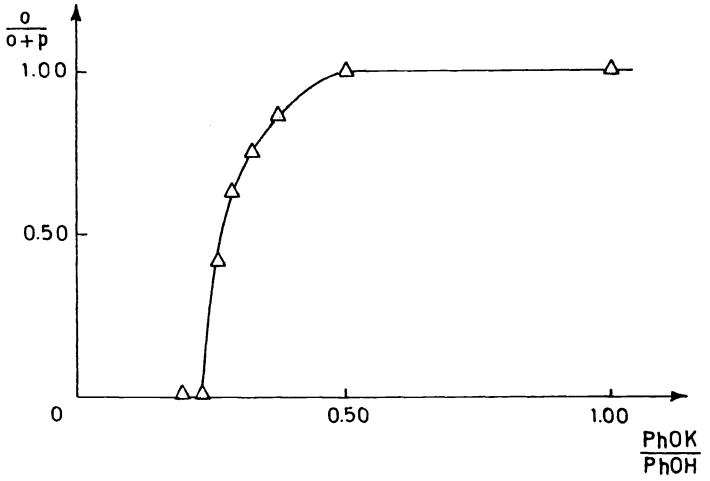
Scheme 15



On the other hand, by favouring a complete transfer of the proton to the alkene, it is possible to induce charge separation, generating cationic species which give rise to charge-controlled reactions (Scheme 15).

Significative results recently obtained in our laboratory agree with this hypothesis (33). In fact, the control of the tert-butylation of phenol, with complete reversal of regioselectivity from ortho to para, was achieved by increasing the Lewis acidity of the catalyst and consequently making easier the carbocation formation (Scheme 16).

Scheme 16



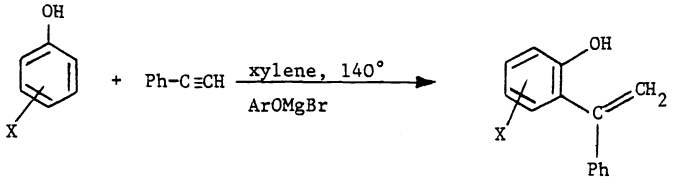
This methodological approach allowed us to develop new useful syntheses, conceived as coordinated Friedel-Crafts processes.

Selective ortho-Vinylation of Phenols

Phenol and related aromatic compounds react with alkynes to give, according to the catalyst employed, aryl-vinyl ethers, dihydroxyarylalkanes, or highly condensed resinous products, (34). In general very little amount, if any, of nuclear vinyl compounds is produced.

In contrast, catalytic amounts of aryloxymagnesium bromides are able to promote the reaction of phenols with phenylacetylene giving rise to the corresponding ortho-vinyl phenols **11** (35) (Scheme 17)

Scheme 17



11

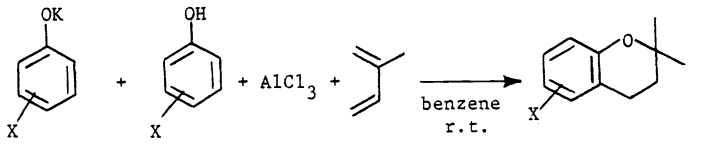
Selective Synthesis of 2,2-Dialkylchromans

The regiochemical control in reactions involving phenols and dienes is an unsolved problem (36). Thus, the acid-catalyzed reactions of phenols and isoprene give rise to a large variety of products. In contrast, we have found that it is possible to obtain a general highly selective chromanation (37) of phenols with dienes according to the aforementioned methodological approach.

The reaction conditions are very strict and probably involve peculiar complexes among phenols, aluminum chloride and isoprene. 2,2-Dimethylchromans are obtained in good yields and exceptionally high selectivity (90-97%).

The procedure is of wide applicability and can be extended without modification to a large variety of substituted mono and polyhydric phenols and dienes (Scheme 18).

Scheme 18



Yield: 90-97%
Convers.: 75-90%

UNUSUAL FRIEDEL-CRAFTS ALKYLATION

The massive literature data on conventional Friedel-Crafts reactions of phenol systems have discouraged so far the use of very basic substrates, such as alkali phenolates, since they were expected to deactivate the Lewis acid catalyst.

In contrast, on the basis of our previous research in this field, we presumed that the simultaneous use of alkali phenolates and Lewis acids would result in the generation of new catalytic species with specific and unusual reactivity behaviour.

Moreover, the presence of these highly basic substrates could reduce the proton acidity which usually develops into conventional Friedel-Crafts processes causing non coordinated intermolecular reactions to occur.

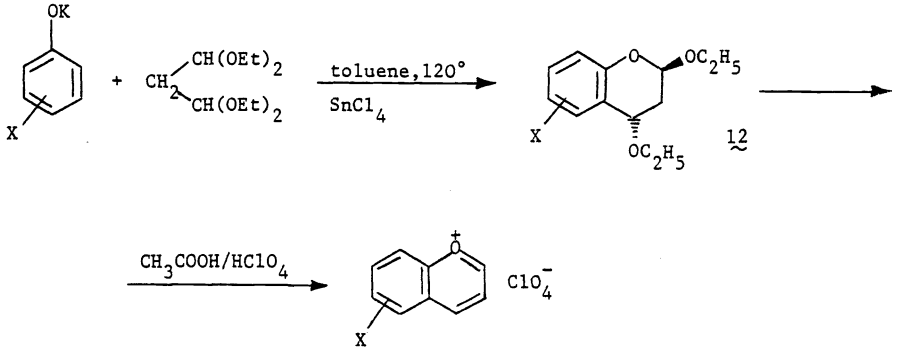
In this context we studied the reactivity of alkali phenolates with suitable reagents in the presence of a stoichiometric amount of Lewis acids ($SnCl_4$, $AlCl_3$).

Synthesis of 2,4-Diethoxychromans and Benzopyrylium Salts

Tin tetrachloride catalyzes the reaction of potassium phenolates with malonaldehyde-bis(diethylacetals) giving 2,4-diethoxychromans (38) with good yields, and very high selectivity (90-95%).

Compounds **12** represent a class of chromans with a hitherto unknown substitution pattern on the heterocyclic ring and may be regarded as potential benzopyrylium salts. In fact, these derivatives are obtained in quantitative yield from **12** by treatment with perchloric acid in acetic acid at room temperature (Scheme 19).

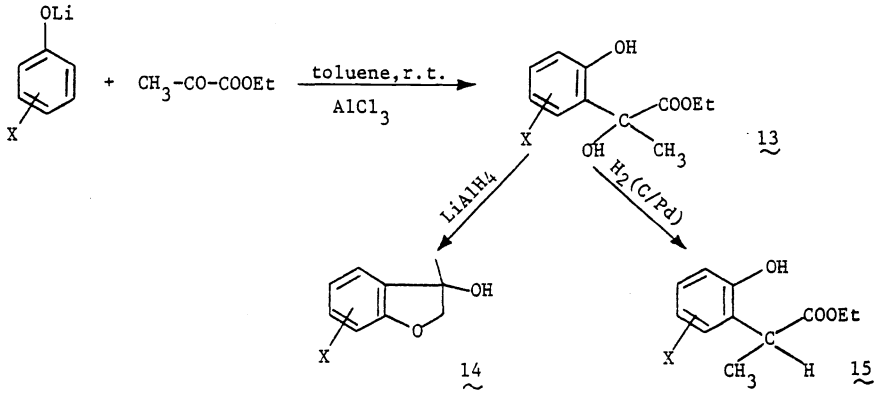
Scheme 19



Synthesis of 2-Hydroxyaryl Lactates, 2-Hydroxypropionates, and Coumaran-3-ols

A mild regiospecific synthesis of ethyl-α-(2-hydroxyphenyl) lactates was performed by treating lithium phenolates with ethyl pyruvate in the presence of aluminum trichloride: compounds **13** are obtained as sole reaction products in good yields and high selectivity (39) (Scheme 20).

Scheme 20



Compounds **13** represent versatile, potentially useful intermediates. In fact, aryl lactates on treatment with lithium aluminum hydride in diethyl ether give the corresponding coumaranols **14** in high yields.

The same products can also be transformed into farmaceutically interesting arylacetic acid derivatives **15**.

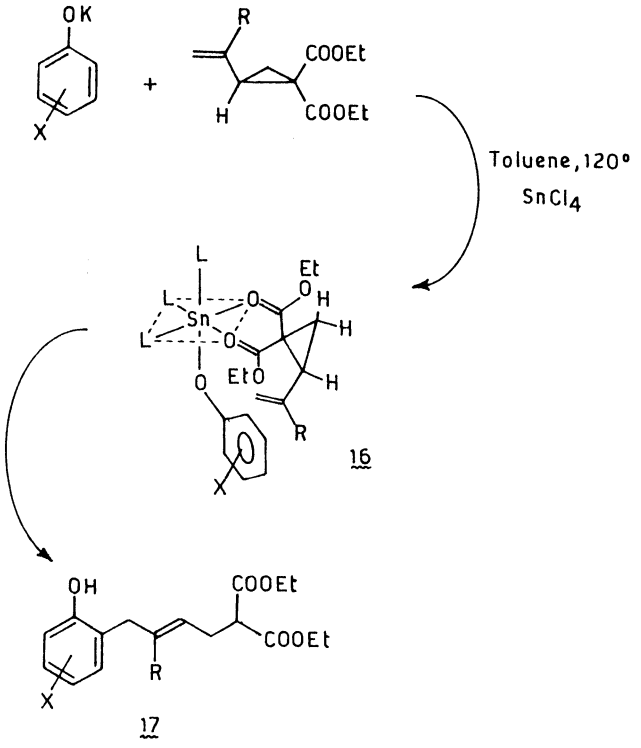
Synthesis of Mycophenolic Acid Congeners

In all the aforementioned reactions the same functional group is directly involved both in the complex formation and in the chemical attack on the phenolic substrate.

However, recently we have observed that diethyl vinylcyclopropan-1,1-dicarboxylates give rise to ortho-attack products (85%), entirely by an 1,7-homoconjugated addition mechanism (40).

This reaction also presents an electrophilic character, since electron withdrawing substituents on phenol reduce or inhibit the reactivity.

Scheme 21



As far as the reaction mechanism is concerned, we can hypothesize that an oriented complex such as **16** plays a crucial role in determining both the ortho-site specific attack as well as the cyclopropane ring opening mode. The reaction occurs at the less hindered terminal position of the double bond (Scheme 21).

Compounds **17** are congeners of a variety of natural products, many of which display pronounced biological activity, as mycophenolic acid, anacardic acid and some components of the urushiol.

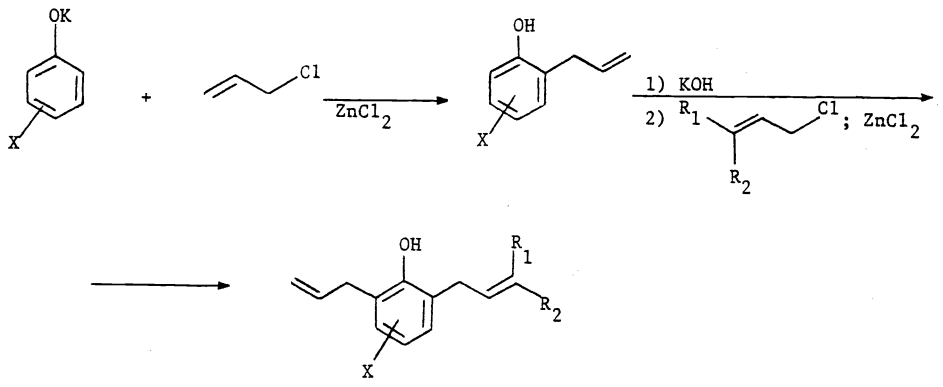
Catalytic Synthesis of Allyl Phenols

According to the methodological approach outlined in this review, we were also able to perform exclusive ortho-allylation of phenols (41).

Indeed, the reaction of potassium phenolate in xylene with allylic halides, in the presence of a catalytic amount of zinc chloride, provides an efficient and extremely selective route to o-allyl phenols (Scheme 22).

The above reaction conditions seem to be inflexible. Control experiments carried out in the absence of zinc chloride gave only moderate yield of aryl allyl ethers with trace amounts of the corresponding o-allyl phenols. On the other hand, phenol alone

Scheme 22



or sodium and lithium phenolates plus zinc chloride in xylene were scarsely reactive. A similar lack of specificity was shown using aluminum trichloride and titanium or tin tetrachloride. Noteworthy is the fact that this method gives only mono-attack products. However, 2,6-diallyl derivatives can also be obtained in subsequent processes starting from mono-allylated products (Scheme 22).

This step-by-step selective ortho-mono-allylation is achieved since trans-salification between reacted and unreacted species is inhibited in the reaction conditions employed.

The template nature and the mild conditions of this reaction are able to mantain the prefixed stereochemistry on the double bond. In fact, geranyl and neryl chloride give rise respectively to (E) or (Z)-2-(3,7-dimethyl-2,6-octadienyl)-phenol with a complete retention of configuration.

Remarkably, geranyl chloride shows a much higher reactivity than neryl chloride.

FINAL REMARKS AND OUTLOOK

The model of bio-organic and organometallic chemistry, which is focused on the control of order in self-catalyzing systems, allows to develop a general unified strategy for organic synthesis (42). In this context we reconsidered classical reactions of phenol systems with the fundamental purpose of improving the selectivity of known processes and developing new ones.

The control of the reaction pathway could be pursued by systematically changing the nature of the complex systems generated by coordination between the reacting species and non-transition metal cations. Thus, it was possible to bring about a fairly large number of highly regioselective reactions leading to important classes of phenolic compounds.

Moreover, by reinvestigating the well known phenol-aldehyde condensation reactions, we disclosed a rational route to regular novolac resins. The stereocontrolled synthesis of isotactic and syndiotactic all-ortho ethylidene-linked polyphenols is the first promising goal which has been achieved, indicating the possibility to extend the basic strategy of classical olefin polymerization to phenol-aldehyde condensation.

One of the aim of the future research in this field is the enantiocontrol of reactions involving phenol salts and their complexes with suitable chiral ligands. Some preliminary results on enantiofacial discrimination have been recently obtained in the hydroxyalkylation of phenols with chloral in the presence of chiral alkoxyaluminum chlorides.

The control of chemical and physical phenomena through the self-organization of artificial systems is and will be, today and tomorrow, the crux of modern organic chemistry which more and more tends to molecular engineering. The results of this research indicate that using the modern achievements of coordination chemistry as guideline, many synthetic challenges of organic chemistry can be successfully faced.

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REFERENCES

1. V.G. Gutmann, Coordination Chem. Rev. **18**, 225 (1976); F. Guibe, G. Bram, Bull. Soc. Chim. 933 (1975).
2. F. Montanari, D. Landini, and F. Rolla, Top. Curr. Chem. **98**, 163 (1981).
3. W.J. Le Noble, Synthesis 1 (1970); S.A.Shevelev, Russ. Chem. Rev. **30**, 844 (1970).
4. G. Casiraghi, G. Casnati, M. Cornia, G. Sartori, and R. Ungaro, J. Chem. Soc. Perkin Trans. 1 2077 (1974).
5. H. Gilman and F. Schule, Rec. Trav. Chim. **47**, 752 (1928).
6. G. Casiraghi, G. Casnati, M. Cornia, and A. Pochini, Gazz. Chim. Ital. **108**, 79 (1978).
7. G. Casiraghi, G. Casnati, M. Cornia, A. Pochini, G. Puglia, G. Sartori, and R. Ungaro, J. Chem. Soc. Perkin Trans. 1 318 (1978).
8. G. Casiraghi, G. Casnati, A. Pochini, and R. Ungaro, J. Chem. Soc. Perkin Trans. 1 805 (1982).
9. G. Casiraghi, G. Casnati, M. Cornia, A. Pochini, G. Sartori, and R. Ungaro, J. Chem. Soc. Perkin Trans. 1 322 (1978).
10. A. Pochini and R. Ungaro, J. Chem. Soc. Chem. Commun. 309 (1976).
11. G. Casnati, A. Pochini, G. Terenghi, and R. Ungaro, J. Org. Chem., in press.
12. G. Casnati, A. Pochini, G. Puglia, and R. Ungaro, Tetrahedron Lett. **23**, 3803 (1982).
13. E. Dradi, A. Pochini, and R. Ungaro, Gazz. Chim. Ital. **110**, 352 (1980).
14. F. Bigi, G. Casiraghi, G. Casnati, and G. Sartori, Synthesis 724 (1980).
15. G. Casnati, A. Pochini, G. Salerno, and R. Ungaro, J. Chem. Soc. Perkin Trans. 1 1527 (1975).
16. A. Pochini and R. Ungaro, Synthesis 617 (1978).
17. G. Casiraghi, G. Casnati, M. Catellani, and M. Cornia, Synthesis 564 (1974).
18. G. Casiraghi, G. Casnati, G. Sartori, and L. Bolzoni, J. Chem. Soc. Perkin Trans. 1, 2027 (1979).
19. G. Casiraghi, G. Casnati, G. Puglia, G. Sartori, and G. Terenghi, J. Chem. Res. (S) 96 (1977).
20. G. Sartori, G. Casiraghi, L. Bolzoni, and G. Casnati, J. Org. Chem. **44**, 803 (1979).
21. A. Pochini, G. Puglia, and R. Ungaro, Tetrahedron Lett. 3897 (1979).
22. G. Casnati, M. Colli, A. Pochini, and R. Ungaro, Chim. Ind. (Milan) **59**, 764 (1977).
23. G. Casiraghi, G. Casnati, E. Dradi, R. Messori, and G. Sartori, Tetrahedron **35**, 2061 (1979).
24. G. Casiraghi, G. Casnati, G. Puglia, G. Sartori, and G. Terenghi, J. Chem. Soc. Perkin Trans. 1 1862 (1980).
25. G. Casiraghi, G. Casnati, G. Sartori, and G.T. Zanafredi, J. Chem. Soc. Perkin Trans. 2 407 (1980).
26. G. Casnati, G. Casiraghi, G. Puglia, G. Sartori, and G. Terenghi, Ital. Pat. Appl. 26.270 A/76 (1976); Ger. Offen 2.736.523 (1977); C.A. **88**,152247 (1978).
27. E. Dradi, G. Casiraghi, G. Sartori, and G. Casnati, Macromolecules **11**, 1295 (1978); G. Casiraghi, G. Sartori, F. Bigi, M. Cornia, E. Dradi, and G. Casnati, Makromol. Chem. **182**, 2151 (1981).
28. E. Dradi, G. Casiraghi, and G. Casnati, Chem. Ind. (London) 627 (1978); M. Cornia, G. Sartori, G. Casnati, and G. Casiraghi, J. Liquid Chromat. **4**, 13 (1981); G. Casiraghi, M. Cornia, G. Sartori, G. Casnati, V. Bocchi, and G.D. Andreetti, Makromol. Chem. **183**, 2611 (1982).
29. G. Casiraghi, G. Casnati, M. Cornia, G. Sartori, and F. Bigi, Makromol. Chem. **182**, 2973 (1981).
30. G. Casiraghi, G. Casnati, G. Puglia, and G. Sartori, Synthesis 124 (1980).
31. G. Casiraghi, M. Cornia, G. Ricci, G. Casnati, G.D. Andreetti, and L. Zetta, Macromolecules, in press.
32. M.C.R. Symons, Chem. Soc. Rev. 1 (1983).
33. Unpublished results from this laboratory.
34. V. Franzen, in "Friedel-Crafts and Related Reactions", Vol. II, G. Olah, Ed., Interscience Publ., N.Y., 1964, p.413.
35. G. Casiraghi, G. Casnati, G. Puglia, G. Sartori, and G. Terenghi, Synthesis 122 (1977).
36. K. Suga, S. Watanabe, H. Kikuchi, and K. Hijikata, J. Appl. Chem. **20**, 175 (1970); G.L.G. Nillsson, H. Sievertsson, and H. Selander, Acta Chem. Scand. **22**, 3160 (1968).
37. L. Bolzoni, G. Casiraghi, G. Casanti, and G. Sartori, Angew. Chem. Int. Ed. Engl. **17**, 684 (1978).
38. F. Bigi, G. Casiraghi, G. Casnati, and G. Sartori, J. Heterocyclic Chem. **18**, 1325 (1981).
39. G. Casiraghi, G. Sartori, G. Casnati, and F. Bigi, J. Chem. Soc. Perkin Trans. 1, in press.
40. G. Sartori, F. Bigi, G. Casiraghi, and G. Casnati, Tetrahedron **39**, 1761 (1983).
41. F. Bigi, G. Casiraghi, G. Casnati, and G. Sartori, Synthesis 310 (1981).
42. P. Heimbach and H. Schenkluhn, Pure and Appl. Chem. **53**, 2419 (1981).