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1-Lithio-1,3-dienes: Useful Building Blocks for Cyclic Compounds

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In this account, our recent results on the application of substituted 1-lithio-1,3-dienes as building blocks for the preparation of a wide variety of cyclic compounds and linear compounds are briefly summarized. Results have revealed that the essential factor which makes 1-lithio-1,3-diene derivatives useful and unique as building blocks is the intra-cooperation between the alkenyllithium moiety and the butadienyl skeleton, notwithstanding that the alkenyllithium moiety itself reacts with organic substrates in the usual way. In addition, the substitution patterns and the nature of the substituents on the butadienyl skeleton have been demonstrated to affect remarkably the reaction pathways of 1-lithio-1,3-diene derivatives.

1. Introduction

Development of organometallic reagents has been one of the most important areas in synthetic chemistry, since practically useful and efficient reagents can remarkably accelerate the advancement of synthesis and related subjects. Around 1998, we found that 1,4-dilithio-1,3-butadiene derivatives **3** reacted with carbonyl compounds,[1] carbon dioxide,[2] and carbon monoxide[3] via unprecedented reaction patterns from those of the well-known monolithio reagents. Later, we realized that this type of dilithio compounds did show cooperation effect and could be used as model compounds for bimetallic regents for organic synthesis.[4,5] For example, 1,4-dilithio-1,3-diene **3a**, generated in situ from its corresponding 1,4-diiodo-1,3-diene **1a** and BuLi, reacted with carbon monoxide to afford 3-cyclopentenone **5a** with high regio- and stereoselectivities (Fig. 1).[3] The cooperative action of the two alkenyllithium moieties towards CO was assumed to be essential for this novel reaction. However, in one accidental case when **1a** containing a small amount of 1-iodo-1,2,3,4-tetrapropyl-1,3-diene (**2a**) as impurity was used, we were surprised to observe that 1-lithio-1,2,3,4-tetrapropyl-1,3-diene (**4a**) also underwent the carbonylation–cyclization reaction and afforded the corresponding cyclopentenone **5a** (Fig. 1).[6]

This serendipitous result interested us very much and we started to pay attention to the potential application of 1-lithio-1,3-dienes **I** (Fig. 2), besides our continuous investigation on 1,4-dilithio-1,3-diene, since new reactions and useful applications might be also achieved from the unique structure of 1-lithio-1,3-dienes **I** and their analogies **II** (Fig. 2). The monolithio reagents **II** can be considered as reactive intermediates readily generated from further treatment of 1-lithio-1,3-dienes **I** with organic substrates. As demonstrated in Fig. 2, there are at least three points should be considered for the reactions of monolithio reagents **I** and **II**, e.g. the alkenyllithium moiety (1), the butadienyl skeleton (2), and the substituent X (3). Obviously, the alkenyllithium moiety is most likely to react with a variety of organic substrates following the common way of monolithio reagents. However, when the substituent X is a functional group, the alkenyllithium moiety in **I** and the Y–Li moiety in **II** may react intramolecularly with X to afford cyclic compounds; In addition, the butadienyl skeletons

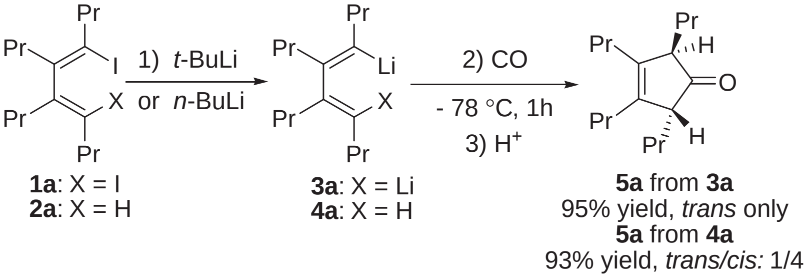


Fig. 1. 1-Lithio-1,3-dienes **4** also underwent the carbonylation–cyclization reaction.

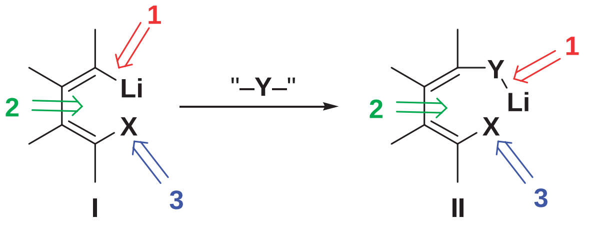
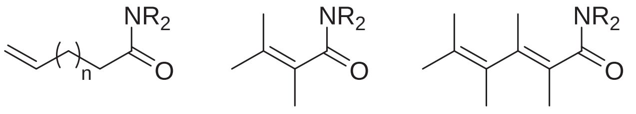


Fig. 2. 1-Lithio-1,3-dienes: reaction patterns and applications.



6 **7** **8**

Fig. 3. Conjugated and non-conjugated unsaturated amides.

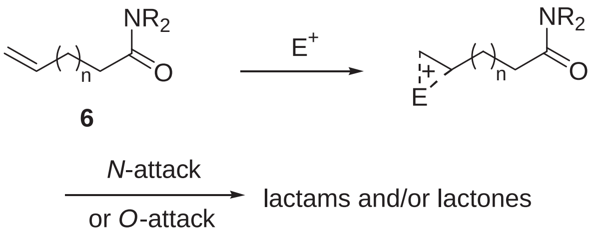


Fig. 4. Electrophilic cyclization of non-conjugated unsaturated amides.

are very useful since they often appear in important compounds including natural products and π-conjugated organic materials and of great possibility for further transformations. The substitution pattern and the nature of substituents including X, which can be adjusted from their synthetic methods, are expected to have remarkable influences on the reactivity of monolithio reagents **I** and **II**. With these interesting features in mind, we have investigated the reactions of monolithio reagents **I** and **II** with a variety of organic substrates since 2002. In this account, we briefly summarize our results obtained in the past three years.

2. Reaction with Isocyanates. Preparation of Multi-Substituted Stereodefined Dienamides and Cyclic Iminoethers

Non-conjugated unsaturated amides **6** and conjugated α,β-unsaturated amides **7** (Fig. 3) have been found to be useful for the preparation of various functionalized lactones, lactams, and oxazolines via electrophilic cyclization.[7] Both *O*-attack and *N*-attack pathways of the electrophilic cyclization are known and competition between these two pathways has been reported (Fig. 4).[7,8] Although a number of preparative methods for dienamides **8** have appeared in the literatures,[8–13] and various heterocycles can be expected from their electrophilic cyclization reaction, few examples have been reported on this kind of investigation.[7,14,15]

By treatment of our in situ generated 1-lithio-1,3-dienes **4** with isocyanates (both *N*-aryl isocyanates and *N*-alkyl isocyanates),[16,17] we developed an alternative synthesis of these conjugated unsaturated amides **8** (Fig. 5) and studied their applications to the preparation of heterocycles via electrophilic cyclization. Surprisingly, our results reveal that these multi-substituted dienamides **8** undergo the electrophilic cyclization exclusively through the *O*-attack pathway to afford cyclic imino ethers, which are seldom obtained via the electrophilic cyclization.[7]

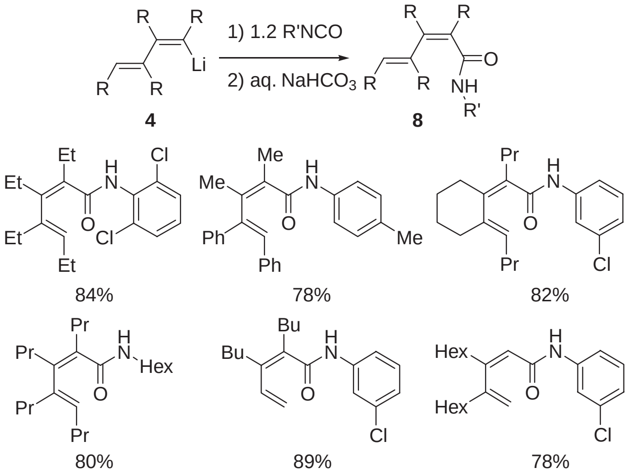


Fig. 5. Reaction of butadienyl lithium reagents **4** with isocyanates leading to dienamides **8**.

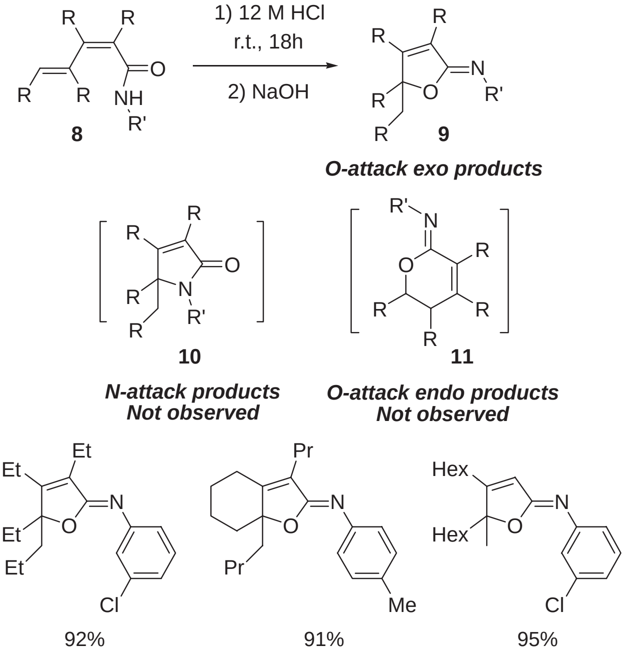


Fig. 6. Acid-promoted cyclization of multi-substituted dienamides **8** affording *exo* cyclic imino ethers **9**.

The best conditions for the cyclization reaction of dienamides **8** were found to be the use of 12 M HCl (1 M = 1 mol dm^{-3}) both as an electrophile and as a solvent at room temperature (Fig. 6). Two unusual features were observed in this synthetically useful reaction. One is that only *O*-attack pathway is involved; the other is that *exo* cyclic imino ethers **9** are obtained as the sole products in excellent isolation yields. No formation of the *N*-attack products **10** or *endo* heterocyclic products **11** were observed. Substitution at the γ position of

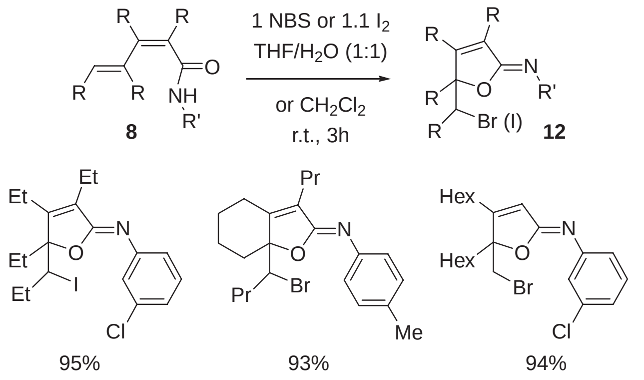


Fig. 7. NBS- or I_2-promoted cyclization of multi-substituted dienamides **8** affording halogenated imino ethers **12**.

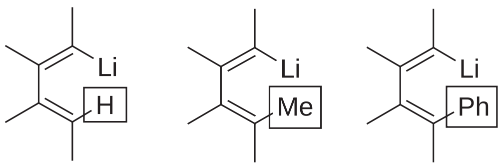


Fig. 8. A variety of 1-lithio-1,3-dienes of different substitution patterns at position 4.

the dienamides and the relative stability of the allylic carbocation might be essential for the *exo* products from *O*-attack.

When NBS and I_2 were used as the electrophiles, the electrophilic cyclization took place also smoothly affording the *O*-attack products, multi-substituted halogenated *exo* iminoethers **12** as the only products in excellent isolated yields (Fig. 7). Formation of the *O*-attack halogenated *exo* iminoethers **12** as the only products could be also addressed by the steric effect of the γ position of the dienamides and the relative stability of the allylic carbocation.[17]

3. Reaction with Aldehydes and Ketones. Preparation of Multi-Substituted Cyclopentadienes, Dienols, and Vinylallenes

In order to develop synthetic methods for conjugated dienols,[18,19] and to investigate the effect of different substituents at position 4 (**X** in Fig. 2) of the butadienyl skeletons, 1-lithio-1,3-diene reagents possessing a methyl substituent and a phenyl substituent at position 4 of the butadienyl skeletons were generated in situ from their corresponding mixed dihalodienes (Fig. 8).[20] Regardless the substituents at position 4, these butadienyllithio reagents reacted with aldehydes or ketones in the usual way to afford conjugated dienols when the reaction mixtures were hydrolyzed with basic solution or even weaker acidic solution such as 3 M HCl.[21] Polysubstituted cyclopentadiene derivatives were obtained in high yields upon hydrolysis using strong acidic solution (Fig. 9).[21,22] Reaction mechanism study revealed that these cyclopentadienes were formed via an acid-promoted cyclization of conjugated dienols. Thus, stereodefined all-*cis*-substituted dienols or a wide diversity of substituted cyclopentadienes can be obtained from the same 1-lithio-1,3-diene reagent and aldehyde by adjusting the hydrolysis conditions (for an example, see Fig. 10).

It was also found out that, depending on the substituents of conjugated dienols, some of which were transformed to cyclopentadiene derivatives more easily than others when treated with acidic solution. For examples, as shown in Fig. 11, in cases of X = Me and Ph, the conjugated dienols could not be transformed to their corresponding cyclopentadiene derivatives in 3 M HCl solution, whilst the conjugated dienol with X = H was totally cyclized at the same acidic condition.

However, reactions of (1-lithio-1,3-dienyl)diphenylphosphine oxides **14** (X = Ph_2PO, Fig. 12) with aldehydes afforded stereodefined vinylallenes **15** via the Wittig–Horner reaction.[23,24]

In this work, we firstly developed a synthetic method for (1-

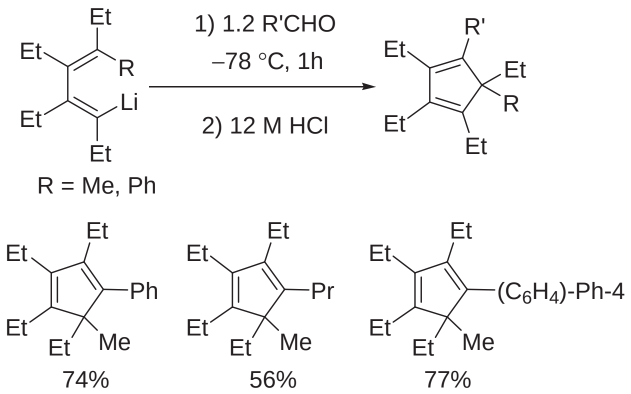


Fig. 9. Formation of cyclopentadiene derivatives by acidic quench of the reaction mixture of 1-lithio-1,3-dienes with aldehydes.

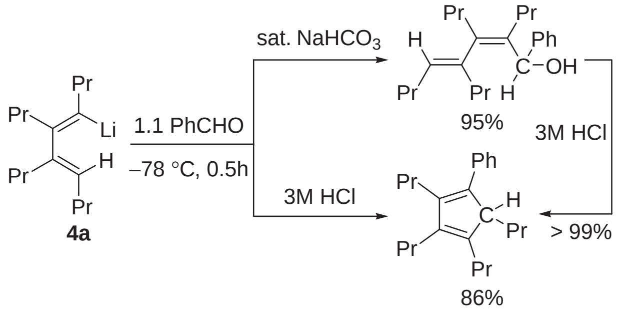


Fig. 10. Work-up dependent formation of conjugated dienols and/or cyclopentadienes.

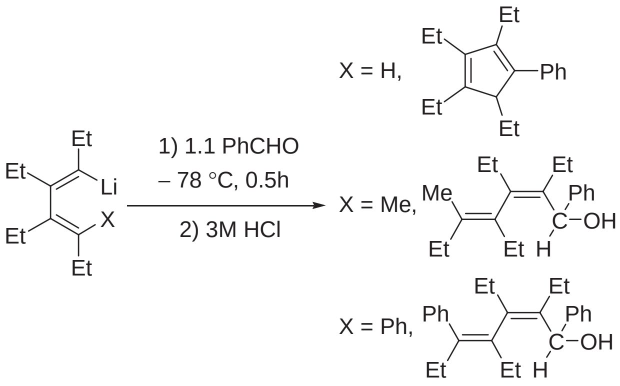


Fig. 11. Substituent-dependent acid-promoted cyclization.

iodo-1,3-dienyl)diphenylphosphine oxides **16** via the zirconocene-mediated chemo- and regio-selective cross-coupling of an alkynylphosphine with a different alkyne followed by iodination.[25] Lithiation of **16a** with 1 molar amount of *n*-BuLi in Et_2O at −78 °C for 0.5 h gave its corresponding (1-lithio-1,3-dienyl)diphenylphosphine oxide **14a** in a quantitative yield. Reaction of **14a** with benzaldehyde at −78 °C for 1 h produced **17a** as a single product in 82% isolated yield after quenching with saturated $NaHCO_3$. When the reaction mixture was allowed to warm to room temperature for 24 h and quenched with saturated $NaHCO_3$, in addition to **17a**, a vinylallene **15a** was also obtained in 30% isolated yield (Fig. 13).

These results suggested dienols **17** came from hydrolysis of intermediate lithium alkoxides **18** and vinylallenes **15** were formed by spontaneous Wittig–Horner elimination of lithium diphenylphosphinate also from **18**.[24] A proposed mechanism for the formation of **15** is given in Fig. 14.

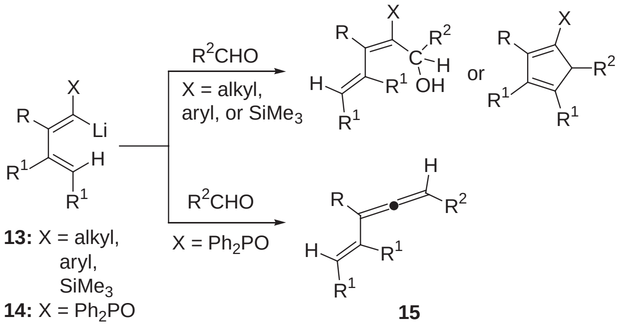


Fig. 12. Reaction of (1-lithio-1,3-dienyl)diphenylphosphine oxides **14** (X = Ph_2PO) with aldehydes afforded stereodefined vinylallenes **15**.

Therefore, promotion of elimination of lithium alkoxides from **18** was critical for successful preparation of vinylallenes **15**. It was finally found out that *t*-BuOK,[26] as a strong co-base, could promote the Wittig–Horner elimination of diphenylphosphinate derivatives from **18**. Thus, when 1 molar amount of *t*-BuOK was added to the reaction mixture and the mixture was sirred for 0.5 h at room temperature, the isolated yield of vinylallene **15a** increased up to 85% as a single product and **17a** was not observed.

As shown in Fig. 15, aromatic, aliphatic, and α,β-unsaturated aldehydes were suitable for the formation of vinylallenes in more than 70% isolated yields under the present reaction conditions. At the same time, the substituent R could be an aromatic or aliphatic group. Obviously, this method provides a convenient way to obtain multi-substituted vinylallenes in high yields by tuning the substituents R and R^1.[27]

Recently, Takeda and co-workers reported an interesting method for allene formation from the reaction of 1-lithio-1-trimethylsilylalkenes with ketones or aldehydes via Peterson elimination (Fig. 16).[28]

4. Cycloaddition Reaction with Organonitriles: Preparation of Multiply Substituted Pyridines, Pyrroles, and Linear Butadienylimines

Development of synthetically useful methods for preparation of *N*-containing heterocycles such as pyridine and pyrrole derivatives has continuously been a major research topic in

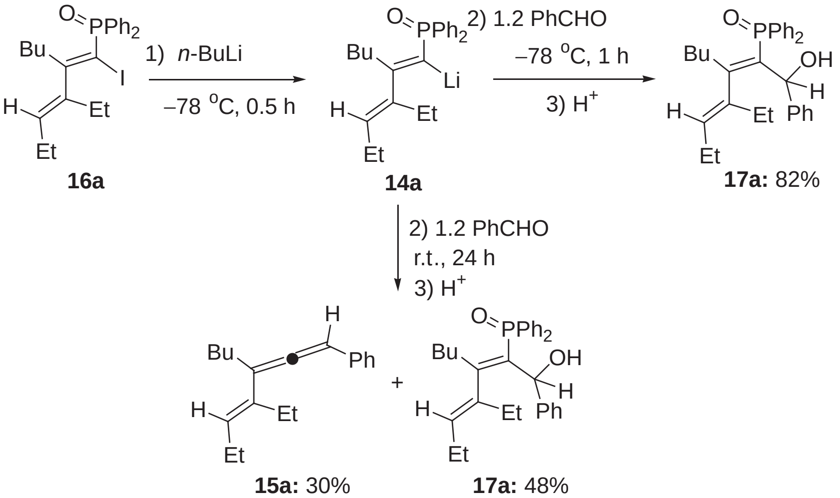


Fig. 13. Formation of alcohols and vinylallenes.

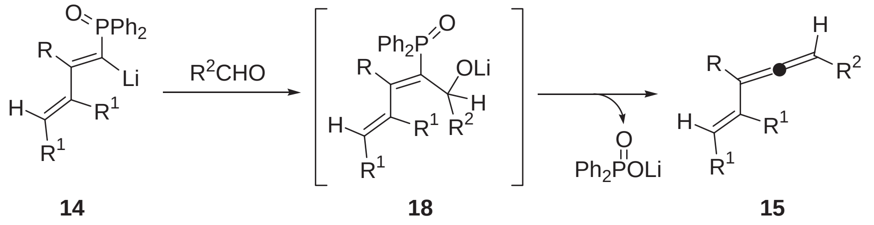


Fig. 14. Wittig–Horner elimination of lithium diphenylphosphinate from **18** affording **15**.

synthetic chemistry.[29,30] Among many synthetic methods for pyridine and pyrrole derivatives with a wide diverse of substitution patterns, the addition reaction of organolithium reagents to organonitriles, which is fundamental in organometallic chemistry, provides an alternative synthetic method.[31] Conventionally, the addition intermediates, *N*-lithioketimines **19**, are intramolecularly trapped by organohalides via nucleophilic substitution to generate *N*-containing heterocycles such as pyridines (Fig. 17).[32,33]

Jones and co-workers obtained dihydroisoquinoline derivatives via selective halogen–lithium exchange reactions of 2-(2-halophenyl)ethyl halides followed by treatment with organonitriles (Fig. 18). This synthesis was realized by the above-mentioned conventional pathway.[32] Similarly, Begtrup and co-workers have recently prepared a series of fused heteroaromatic frameworks including 6-substituted phenanthridines, 4-substituted 1*H*-pyrazolo[4,3-*c*]quinolines, 9-substituted 1*H*-pyrazolo[3,4-*c*]quinolines, and 1,4-dihydrochromeno[4,3-*c*]pyrazoles (Fig. 18).[33]

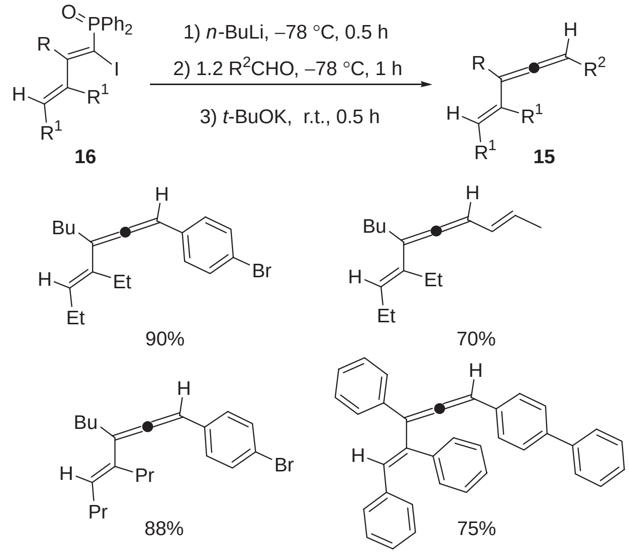


Fig. 15. Formation of vinylallenes from *t*-BuOK-promoted reaction of (1-lithio-1,3-dienyl)diphenylphosphine oxides and aldehydes.

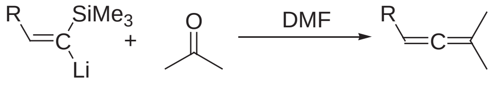


Fig. 16. Formation of allenes via Peterson elimination.

However, 1-lithio-1,3-dienes behaved unusually and underwent a novel cycloaddition of organonitriles (Fig. 19).[34,35] Depending on the substitution patterns of the butadienyl skeletons, substituted pyridines, pyrroles, and/or linear butadienyl imines were formed in good to excellent yields. The *N*-lithioketimines **21** must be formed as the reactive addition intermediates at −78 °C, because hydrolysis of the reaction mixture at −78 °C afforded the linear imines **22** in high yields. With the rise of reaction temperature, intramolecular lithiation–cyclization took place to form cyclic intermediates, which afforded pyridine derivatives and/or pyrrole derivatives as the final products.

4.1 The Order of Elimination Was Found to Be LiCl > Me$_3$SiLi > LiH. The order of elimination of RLi from the lithiated cyclic *N*-containing intermediates **23** was found to be LiCl > LiSiMe$_3$ > LiH. No elimination of alkyllithium salts was observed. For examples (Fig. 20), 1-lithio-1,3-diene **4b** reacted with PhCN affording the tetrahydroisoquinoline **24b** in 85% isolated yield. Elimination of LiH rather than BuLi took place. When trimethylsilyl-substituted 1-lithio-1,3-diene **4c** and **4d** were used, elimination of LiSiMe$_3$ rather than LiH took place for **4c**, whilst LiCl was eliminated instead of

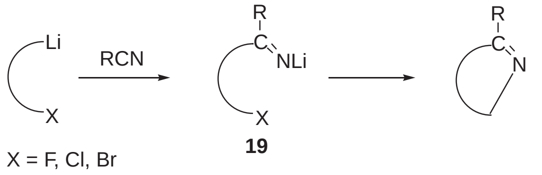
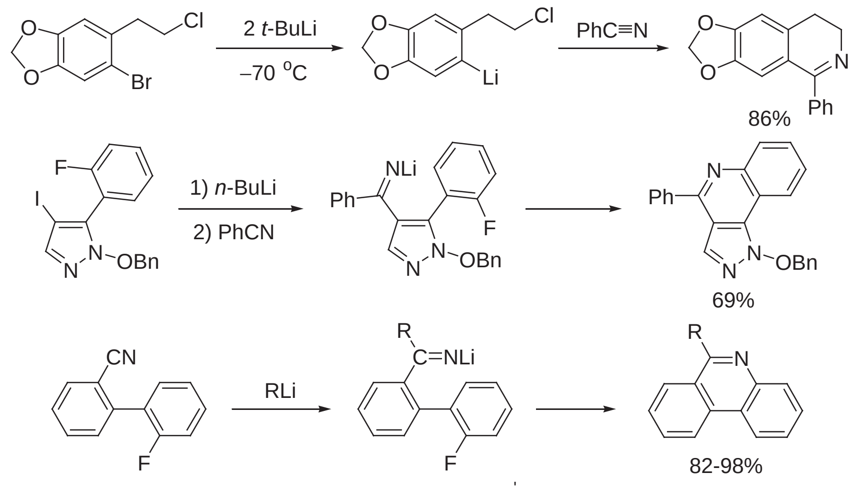


Fig. 17. Conventional procedure for preparation *N*-containing heterocycles via nucleophilic substitution.



R = Alkyl, Aryl or R'$_2$N

Fig. 18. Examples of application of intramolecular nucleophilic substitution.

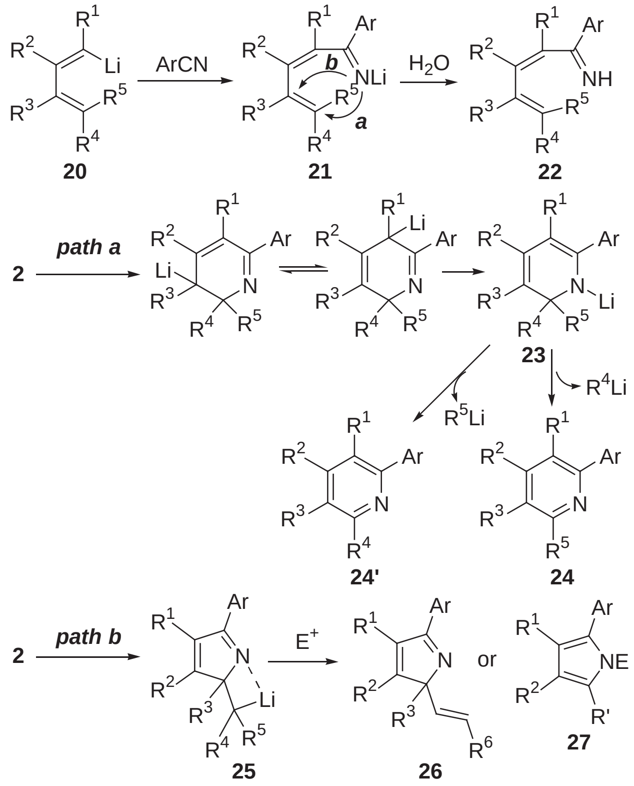


Fig. 19. Reaction of paths of lithio butadienes with organonitriles.

$LiSiMe_3$ in the case of **4d**. Further, in order to know whether EtLi or LiCl is eliminated when both are presented in the intermediate, we prepared the monolithio reagent **4e**. As expected, LiCl was selectively eliminated. In addition to the pyridine derivative **24e**, a pyrrole derivative **26a** was also formed when the reaction was carried out at room temperature. We also prepared the lithium reagent **4f** possessing a methyl group at position 4. But no intramolecular lithiation–cyclization took place even at elevated reaction temperatures, probably due to the steric effect of the methyl group.

4.2 Competition between 5-*exo* and 6-*endo* Cyclization Was Found to Be Responsible for the Formation of Either Pyrroles or Pyridines. As mentioned above, in the case of **4e**, along with formation of the expected pyridine derivative **24e**, unexpected pyrrole derivative **26a** was also obtained at room temperature. If the reaction temperature was increased to 50 °C immediately from −78 °C, the pyridine derivatives **24** were not obtained at all in most cases, while the pyrrole derivatives **26** were obtained as the only final products in high isolated yields.

As a rationale shown in Fig. 21, a competition between **path a** and **path b** is operating in this reaction. The involvement of **path b** in this reaction may be due to the steric hindrance of the chlorinated carbon center and the electro-withdrawing effect of the chlorine atom. These results show that **path b** is thermodynamically favored, affording the five-membered intermediates **25**. For the formation of pyrrole derivatives **26**, although we could not successfully trap the intermediates **25**, a carbene-like intermediate **28** must be generated and followed by 1,2-H shift to afford the pyrrole derivatives **26**.

4.3 The Substitution Patterns on the Butadienyl Skeletons Remarkably Affected the Reaction Paths. Reaction of 1,2-disubstituted 1-lithio-1,3-dienes **29** with organonitriles at −78 °C generated the linear butadienyl imines **30** upon quenching with aqueous $NaHCO_3$ (Fig. 22). When the temperature was increased to a higher temperature, in addition to **30**, pyrrole derivatives **27** appeared. If the reaction was carried out at reflux, the pyrrole derivatives **27** were obtained as the sole products in high isolated yields. No pyridines were formed (except the case of PyCN).

A proposed mechanism for the formation of pyrrole derivatives **27** from **31** is given in Fig. 23. The 5-*exo* intramolecular lithiation–cyclization of **31** took place to afford the lithio pyrrole intermediates.

Interestingly, when the substitution pattern on the butadienyl skeletons of monolithio reagents was changed to 2,3-disubstituted patterns, for example, 2,3-dihexyl-1-lithio-1,3-diene **32**, its reaction with organonitriles afforded pyridine derivatives **24** as the only products via **33** (Fig. 24). No pyrrole derivatives were formed in these cases.

The above results obviously demonstrated that the substitution patters on the butadienyl skeletons of the monolithio reagents remarkably influenced the reactivity of these lithium reagents. Substituents at positions 3 and 4 of the skeleton of 1-lithio-1,3-butadienes played an important role on the reaction paths leading to either 5-*exo* or 6-*endo* cyclization.

5. Formation of Silole Derivatives via Intramolecular Nucleophilic Substitution

Nucleophilic activation and substitution of organosilicon groups are fundamental in organosilicon chemistry and in developing synthetic methods.[36] Pentavalent organosilicates have been proposed as key intermediates in organolithium-mediated nucleophilic activation and substitution reactions of organosilicon compounds.[36,37] Klumpp and co-workers reported first observation of pentaorganosilicates **34** by low-temperature NMR spectroscopy in a special case (Fig. 25).[37a]

On the other hand, multi-substituted silacyclopentadienes (siloles) are useful compounds for the study of Si-containing materials.[38,39] Thus, preparative methods for these compounds have been of great interest.[38,39]

In our work,[40] when 1-bromo-4-trimethylsilyl-1,3-diene **35** was treated with 2 equivalents of *t*-BuLi as usually done, silole derivative **37** (R = Et) was obtained as listed in Table 1. A variety of substituents on the Si atom, such as methyl, ethyl, isopropyl, vinyl, and phenyl could be used to afford silole derivatives in good to excellent yields.

As shown in Table 1, one of the substituents of $SiR^1R^2R^3$ was eliminated. The methyl group rather than the isopropyl group in **35b**, the vinyl group rather than the methyl group in **35c**, and the phenyl group in **35d** were abstracted respectively. This order of elimination can be well interpreted by the relative stability of the pentaorganosilicate intermediates (Fig. 26).[36,37]

6. Formation of Spiro Cyclopentadiene Derivatives via Dearomatizing Anionic Cyclization

Organolithiums tethered to aromatic rings (compound **A** in Fig. 27) have been reported to undergo cyclization reactions

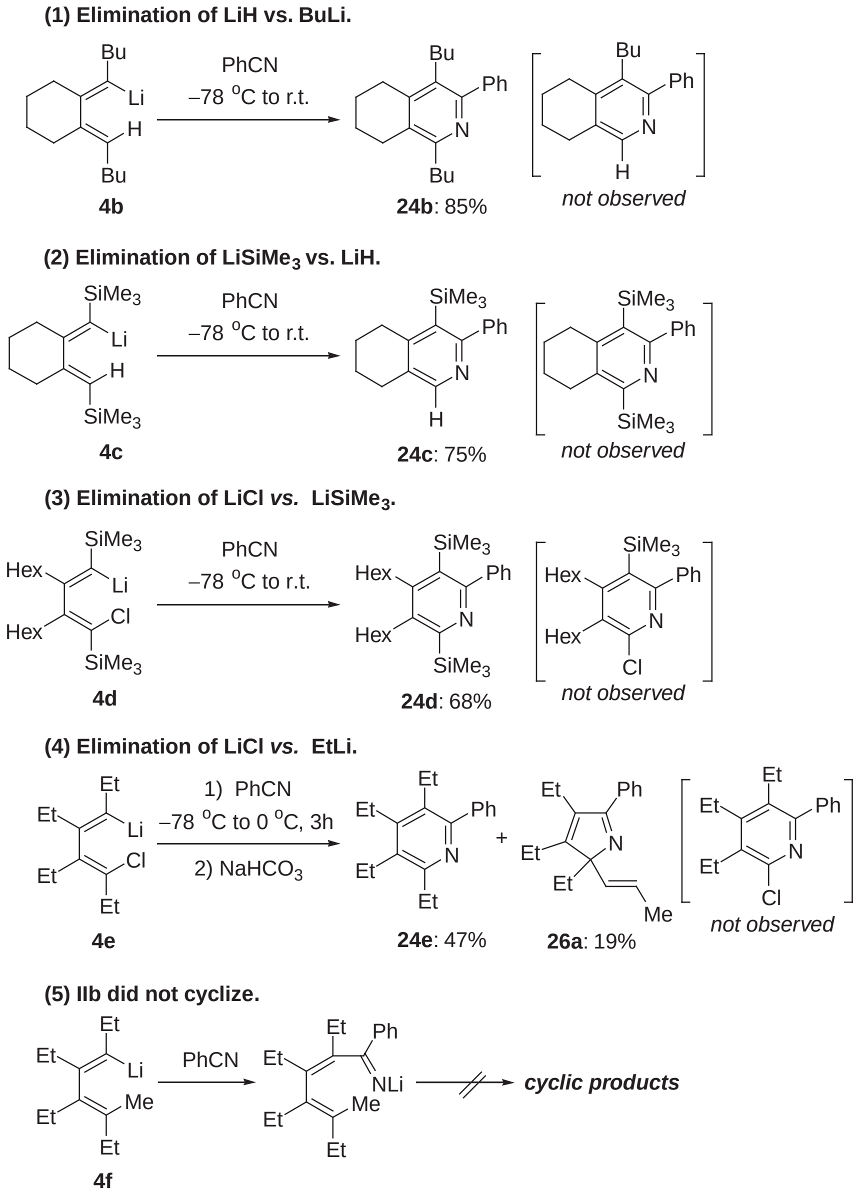


Fig. 20. Order of elimination.

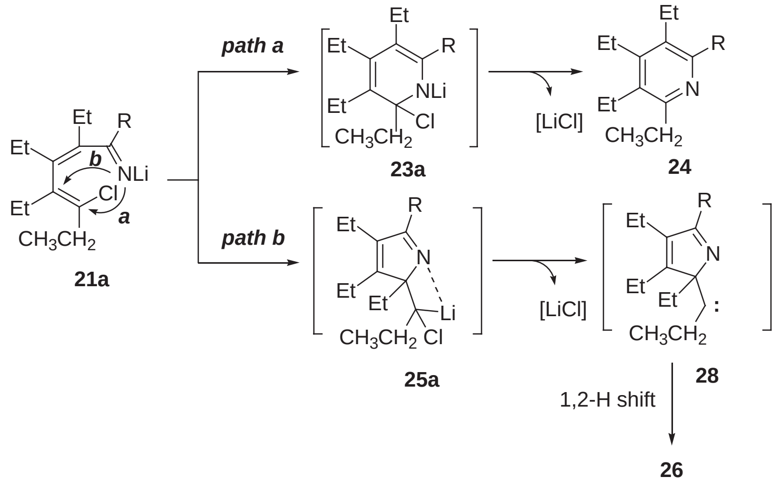


Fig. 21. A proposed reaction mechanism: 5-*exo* vs 6-*endo* cyclization.

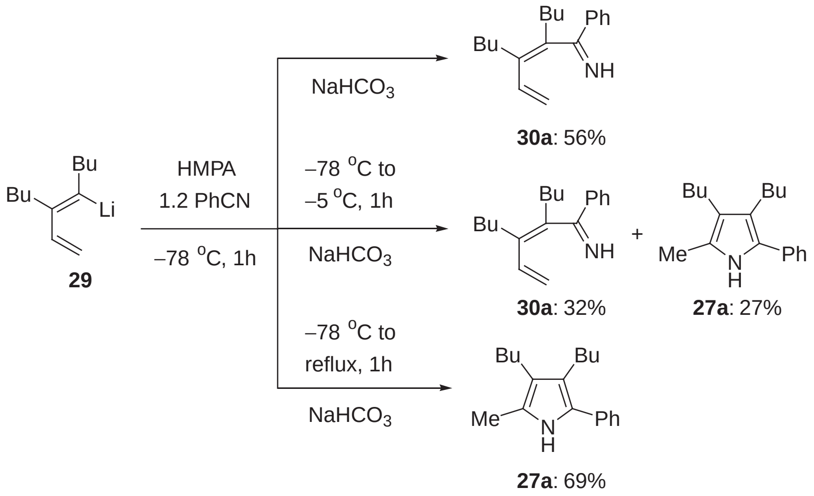


Fig. 22. Reaction of 1,2-disubstituted 1-lithio reagents with organonitriles.

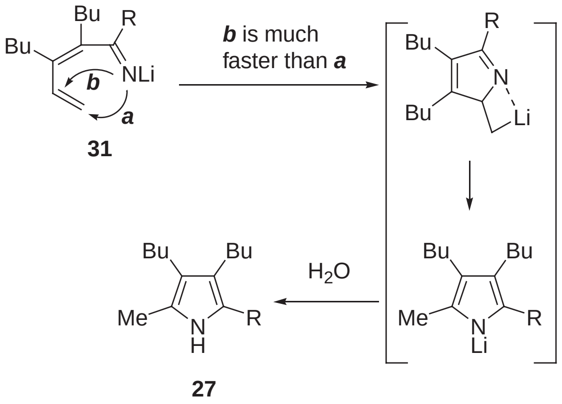


Fig. 23. Proposed mechanism for the formation of **26** from **30**.

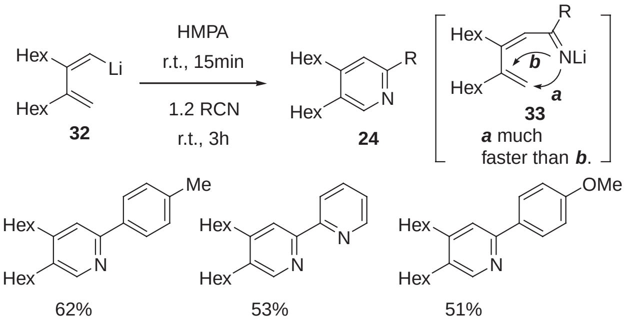


Fig. 24. Reaction of 2,3-disubstituted 1-lithio reagents with organonitriles.

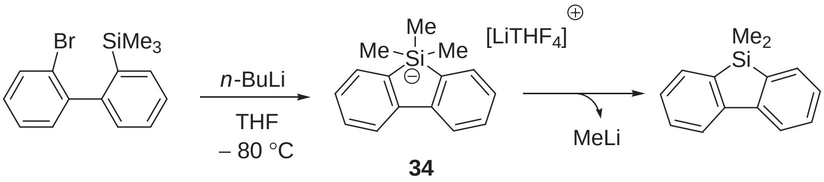


Fig. 25. Observation of pentaorganosilicates.

via nucleophilic addition of the organolithium to the π-system of the aromatic ring.[41–43] As the in situ generated organolithium intermediates in this intramolecular nucleophilic addition of **A**, two types of intermediates can be expected. As shown in Fig. 27, the fused ring system **B** via reaction **Type I** and the spiro ring system **C** and/or **D** via reaction **Type II** may be generated.

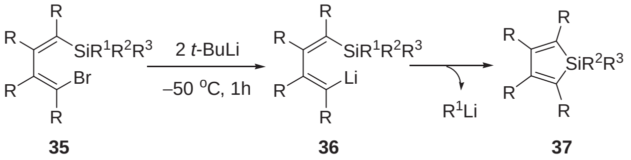
Several reports have demonstrated formation of the fused ring system **B**,[41–43] especially in the case of aromatic amides including *N*-benzylbenzamides, *N*-benzylnaphthamides, sulfonamides, and phosphonamides. Both benzo-fused compounds via rearomatization of **B** and dearomatized bicyclic products have been prepared from **B**, as mainly carried out by Clayden and co-workers (Fig. 28).[41–44] Synthesis of arylcycloalkanes from ω-alkenyl benzylselenides was also achieved via carbolithiation of C–C double bond followed by intramolecular nucleophilic addition to the π-system of the aromatic ring. Rearomatization gave the final product with elimination of LiH (Fig. 28).[44]

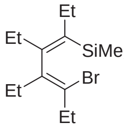
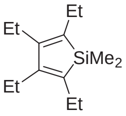
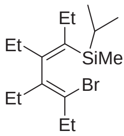
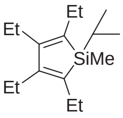
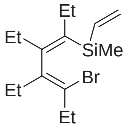
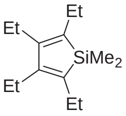
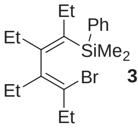
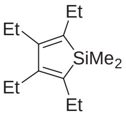
However, although the spiro ring system **C** and/or **D** is structurally and synthetically interesting, and can be expected via reaction **Type II**, the only example involving *N*-benzylpyridine and quninoline carboxamides was mentioned in a recent publication by Clayden and co-workers.[43a]

Interestingly, as given in Fig. 29, when 1-iodo-4-naphthyl-1,3-diene **38** was treated with 2 molar amounts of *t*-BuLi, an unprecendented cyclization reaction took place affording the spiro tricyclic products **39** and **40** in 90% combined yield. In comparison with the reaction types described in Fig. 27, monolithium intermediate **41** (Fig. 29) should be firstly formed, which then immediately undergo nucleophilic addition of **Type II** to form stable organolithium reagents **42** and **43**.[45]

To further demonstrate the usefulness of this novel intramolecular nucleophilic addition reaction and to prepare otherwise unavailable spiro compounds, we treated the above reaction mixture with a variety of electrophiles (Fig. 30). Although the reason is not clear yet, the corresponding products **44** were obtained as the only isomer in good to excellent isolated yields.[45] Isomers **45** were not detected. As a demonstration, Figure 31 shows the single-crystal X-ray structure of spiro carboxylic acid derivative **44d**, which was obtained in 69% isolated yield by treatment of the dearomatized lithio intermediate with CO_2.[45]

Table 1. Formation of Siloles by Lithiation of 1-Bromo-4-trisubstituted Silyl-1,3-butadiene Derivatives



Bromo compound **35**	Product **37**/%	
 **35a**		88 (60)
 **35b**		99 (80)
 **35c**		69
 **35d**		78

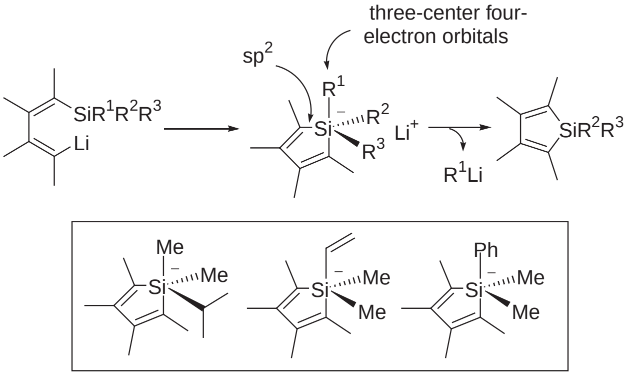


Fig. 26. The relative stability of the pentaorganosilicate intermediates determines which group is eliminated.

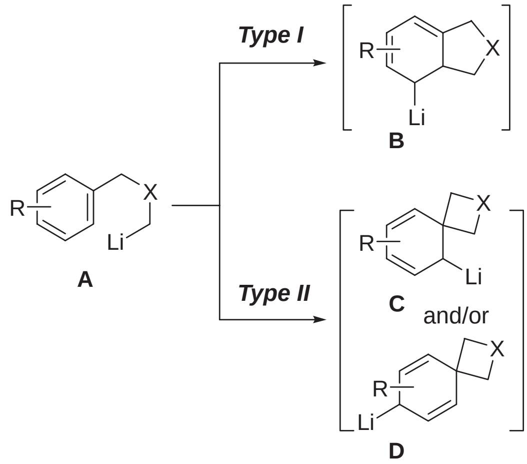


Fig. 27. Possible patterns of intramolecular nucleophilic addition of organolithium to the π-system of aromatic rings.

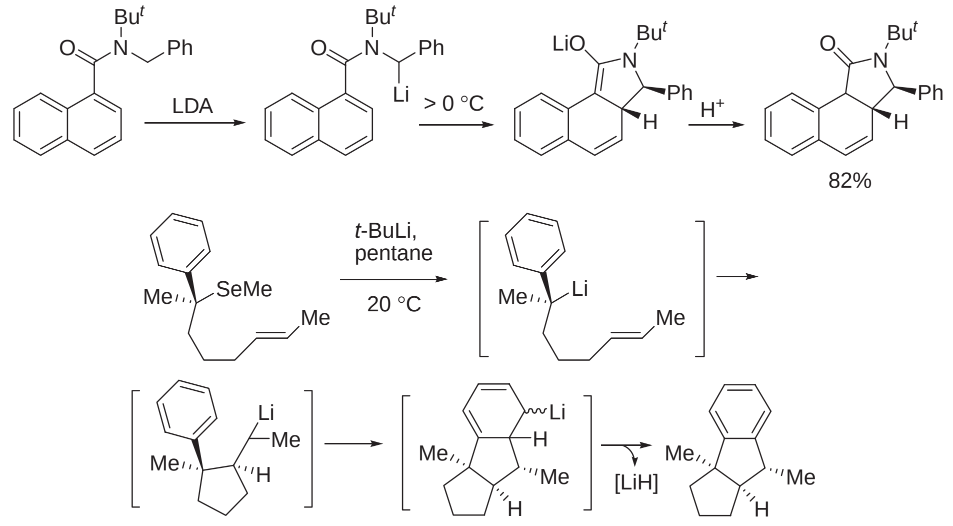


Fig. 28. Selected examples of fused-ring formation via the intramolecular nucleophilic addition.

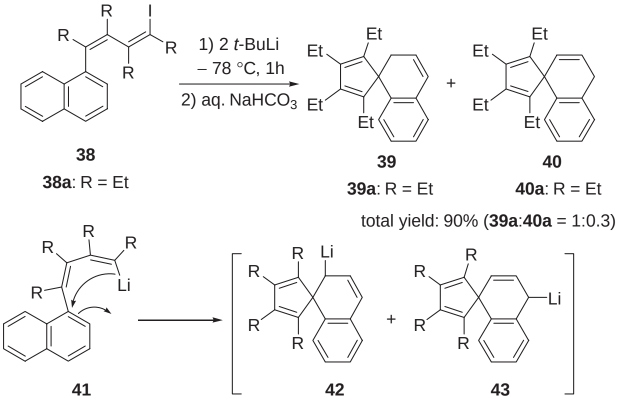


Fig. 29. Intramolecular dearomatizing anionic cycloaddition leading to spiro products.

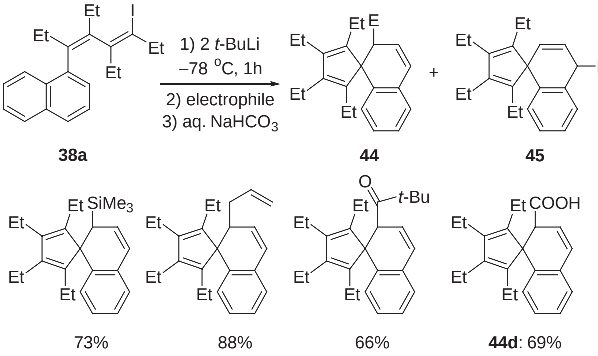


Fig. 30. Further reaction with a variety of electrophiles.

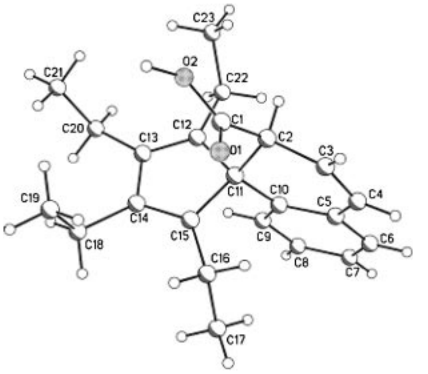


Fig. 31. Single-crystal X-ray structure of **44d**.

Conclusion

As our results have so far demonstrated (Fig. 32), the intra-cooperation of the alkenyllithium moiety and the butadienyl skeleton including their substituents is very effective and unique, leading to a variety of cyclic and linear compounds, which are otherwise difficult to obtain.

Conceptually, more diversified structures can be synthesized by using this monolithio reagent. For example, analogous 1-metalla-1,3-diene derivatives can be readily generated either from 1-lithio-1,3-dienes via transmetallation or directly from 1-halo-1,3-dienes via oxidative addition. Synthetically useful methods can be thus expected from such 1-metalla-1,3-diene derivatives. As one example shown in Fig. 33, equimolar amount of $FeCl_3$ at 0 °C in diethyl ether solution could mediate the dimerization of 1-lithio-1,3-dienes to afford multiply substituted and stereodefined all-*cis* tetraenes.[46]

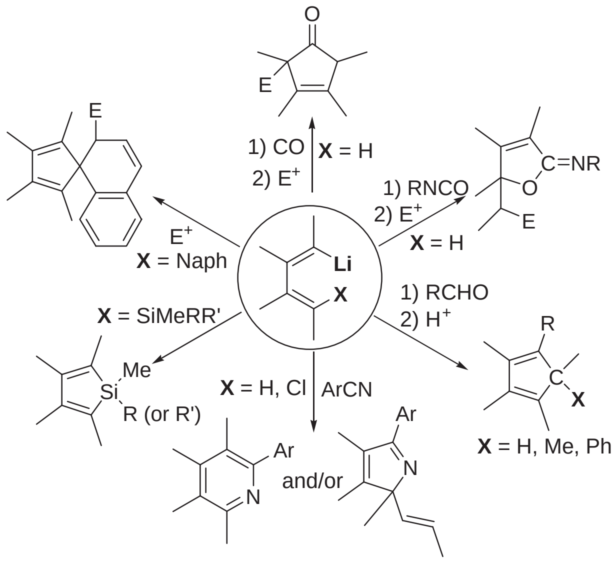


Fig. 32. Summary of reactions of 1-lithio-1,3-dienes affording a variety of cyclic compounds: demonstration of cooperative effect.

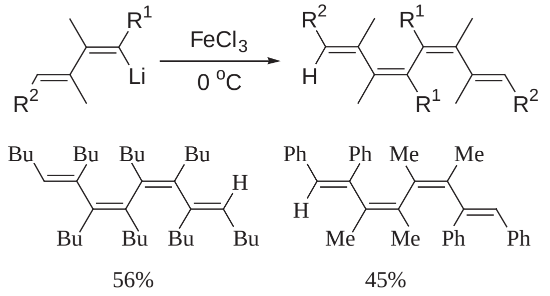


Fig. 33. $FeCl_3$-mediated dimerization of 1-lithio-1,3-dienes affording stereodefined tetraenes.

Further investigation into the reactivity of 1-lithio-1,3-dienes as a useful reagent is still going on in our research group, with special attention to the utilization of functional substituents.

The work reported in this account would not have been possible without the excellent efforts by my past and present coworkers and students, whose names appear in the references. Financial support from the Natural Science Foundation of China, the Major State Basic Research Development Program, the State Key Laboratory of Organometallic Chemistry, Dow Corning Corporation, and Peking University is gratefully acknowledged. The author also would like to thank Cheung Kong Scholars Programme, Qiu Shi Science & Technologies Foundation, BASF, and Eli Lilly China.

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