protective groups (CBZ, formyl, and acetyl), including the easily removable ones; and (iii) various amino acid derivatives including both L- and D-isomers and dipeptides were utilized as nucleophiles.

In summary, a radically altered stereospecificity of subtilisin in organic solvents affords facile enzymatic preparation, impossible in water, of diverse peptides containing D-amino acids, thus providing a new synthetic route to bioactive peptides.

Thermal Generation and Dimerization of [4]Metacyclophane

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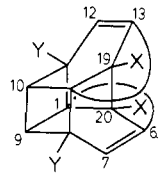
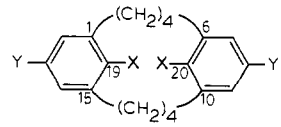
The field of cyclophanes with very short bridges continues to bring forth intriguing results.[1] While [5]metacyclophane (1977)[2] and [5]paracyclophane (1985)[3] have already been synthesized, attempts to bridge a benzene ring with four atoms have not yet yielded an isolable compound. [4]Paracyclophane, predicted by Schaefer et al. "on statistical grounds" to be synthesized in 1992,[4] has recently been generated photochemically at low temperatures, intercepted with alcohols,[5,6] and identified by its UV spectrum.[6] [4]Metacyclophane (**2a**) is expected to be less strained and more stable than its para isomer and thus appears to be overdue in this series.

Our previous attempts[7] to obtain **2a** by irradiation of its Dewar isomer **1a**[8] were unsuccessful because **1a** furnished the prismane isomer in a quantitative escape reaction. In the course of those studies, we observed on GCMS small quantities of compounds with double mass. An investigation of the dimer formation has now furnished good evidence for the involvement of **2a** and has revealed some fascinating reactions and products.

Depending on the thermolysis conditions, **1** yielded different product mixtures (see Scheme I and Table I). Compounds **3** and **12**[9] were known. The structures of **10** and **11** could be assigned



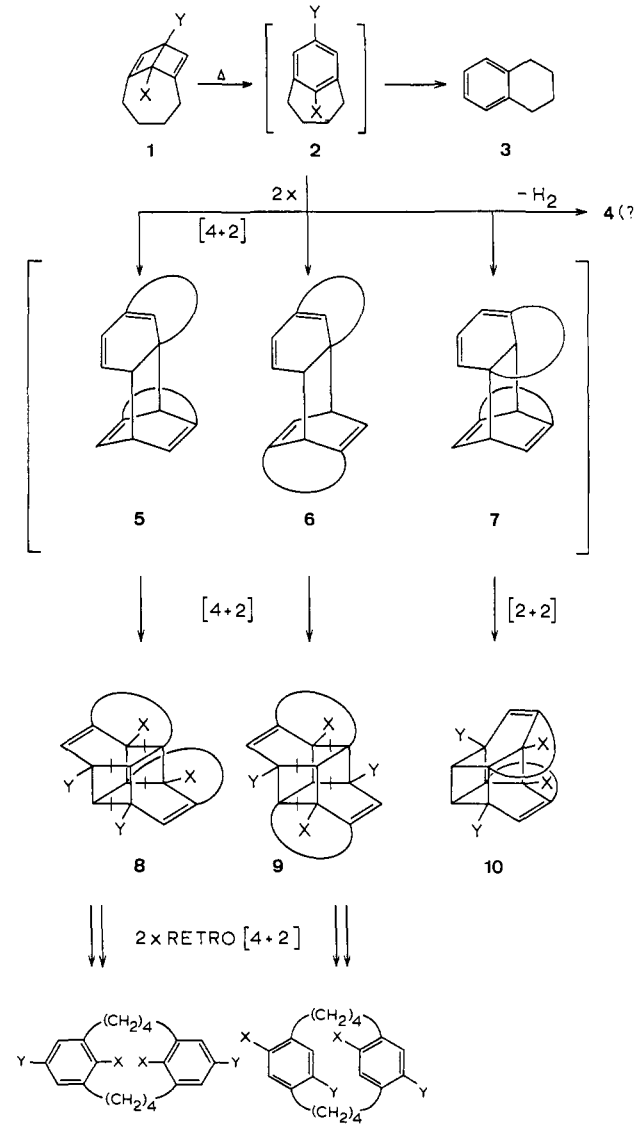
10



11

from their spectral data and from those of deuteriated derivatives.[10]

Scheme I[a]



1 **2** **3** **5** **6** **7** **8** **9** **10** **11** **12**

[a] **a**; X = Y = H, **b**; X = D, Y = H, **c**; X = H, Y = D.

The dehydrogenated dimer **4** was not further characterized. Unfortunately, **8**, **9**, and probably three other dimers formed in comparable amounts turned out to be so similar in their physical properties that we have not yet been able to separate them by HPLC or by preparative GC; the latter technique suffers from the additional disadvantage that some decomposition occurred at the high injector temperatures required due to the low volatilities of the products. Therefore, their structural assignment is tentative; it is based on GCMS and a few typical ^{1}H NMR signals,[10] and on their thermal behavior.

When **1** was injected into the gas chromatograph (injector temperature 300 °C, Table I, entry 1), **10a** was the main component of the product mixture. Heating **1a** at 200 °C in a KOH-conditioned[11] sealed ampoule gave, besides much polymer, the same substances, but with drastically changed product ratios, and **12a** as the main component (77%; entry 2). Mechanistically revealing were the ampoule experiments at lower temperatures (entries 3 and 4); here, according to GCMS and NMR analysis, a mixture of at least five dimers, including **8a** and **9a**, was obtained.

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(11) Reactions in unconditioned ampoules gave variable results; in most cases, large amounts of **3** (up to 60%) were obtained. In a run with 2 mol % *p*-toluenesulfonic acid, the yield of **3** rose to 90%.

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Table I. Products from the Thermolysis of **1a**

entry	conditions			products[a]						
		1a (mg)	T (°C)	*t* (min)	**3a**	**4a**	**8a** + **9a** + isomers	**10a**	**11a**	**12a**	recovery[b]
1	GC	7	300[c]		5	1		89	4	1	50[d]
2	ampoule	5	200[e]	5	<1	4	<1	13	6	77	ca. 20[d]
3	ampoule	5	175[e]	5	2		>95			1	ca. 100[f]
4	ampoule	5	150[e]	5	<1		>90				*g*
5	ampoule	*h*	200	5	1	8		2	10	54	ca. 20[f]

[a] In percent of total recovery; furthermore, <1% of methylindanes was present in many runs. [b] In percent of **1a**. [c] Injector: 300 °C; oven: 200 °C; 1.5 m 15% SE-30 on Chromosorb W; 60 mL H_2/min. [d] Isolated yield (preparative GC). [e] A KOH-pretreated Pyrex ampoule of 0.5-mL contents was used. [f] Determined from ^1H NMR with C_6H_6 as internal standard. [g] Not determined; 6% of **1a** was present. [h] The product mixture (**8a**, **9a** + isomers) from entry 3 was used.

When this mixture was heated separately to 200 °C (entry 5), it lead to extensive formation of polymer (broad signals in the ^1H NMR spectrum) and a ratio of **11a**:**12a** similar to that in entry 2; this indicates that **8a** and **9a** are intermediates for **11a** and **12a**.

The most unexpected aspect of these reactions is the rather clean transformation of the "*meta*"-bridged **1a** to the *para*cyclophane **12a**; this is all but straightforward and signals deepseated rearrangements. Remarkable also is the formation of (substituted) arene cage dimers[12-14] like **8a-10a** in a single operation. While the parent benzene dimer corresponding to **10a**, which has C_2 symmetry, is known,[12] the D_{2h} benzene dimer corresponding to **8a** and **9a** has not been reported to our knowledge.

A rationalization of our results is given in Scheme I. The essential postulate is the thermal isomerization of **1a** to **2a**. This step is presumably slightly endothermic (MNDO:$\Delta H_f°$ (**1a**) = 74.6 kcal·mol^{-1}; $\Delta H_f°$ (**2a**) = 77.1 kcal·mol^{-1})[15] and rate determining; the high aromatization temperature required for a short-bridged Dewar benzene has precedent.[16] The ensuing transformation of **2a** to **11a** (or to **12a**, respectively) involves four remarkable [4 + 2] reactions (Scheme I). The first two are Diels-Alder reactions and proceed via **5a** to **8a** (or, for a different orientation of the two bridges, via **6a** to **9a**).[17] The ease of these unprecedented benzene dimerizations stems from the high-energy content of **2a** (e.g., MNDO: ΔH (2 × **2a** → **9a**) = −59.5 kcal·mol^{-1}). The two following steps from **8a** to **11a** (or from **9a** to **12a**), are retro versions of the first two [4 + 2] reactions. While **2a** → **8a** involves the formation of the four vertical bonds of the cage, the indicated four horizontal bonds are cleaved for **8a** → **11a**. This latter process is thermodynamically favorable because it furnishes two unstrained benzene rings.[18] Note that the initially unexpected para substitution pattern of **12a** follows naturally from the proposed mechanism.

Support for Scheme I comes from deuterium-labeling experiments: **1b** gave **11b** and **12b**; **1c** gave **11c** and **12c**, which is identical with **12b**. The position of the label in **11b,c** was unambiguously deduced from the ^1H NMR spectra.[10] Also, **1c** furnished **8c** and **9c** with the predicted changes of the assignable ^1H NMR signals (e.g., collapse of the olefinic doublets at δ = 6.09 and 6.12 ppm to (br) singlets).

The genesis of **10a** is less obvious. It may proceed as depicted by a [4 + 2] dimerization of **2a** to yield **7a**. An intramolecular Diels-Alder reaction of **7a** (corresponding to that of **5a** or **6a**) is prohibited by bridge strain; instead, a formal [2 + 2] addition may get a chance to furnish **10a**. Again, deuterium labeling[10] supports this course of events.

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Supplementary Material Available: Listing of spectral, GCMS, and HRMS data (4 pages). Ordering information is given on any current masthead page.

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N-Substituted Organo(silyliminomethyl)stannanes: Synthetic Equivalent to Organosilylcarbonyl Anion and Carbonyl Dianion

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Acylmetals are often involved as important intermediates in transition-metal-catalyzed reaction with carbon monoxide. Synthetic utilities of some acylmetal compounds such as acylferrate anions[1] and related organometallic compounds[2] have been demonstrated. However, acylmetals, which are readily available and widely utilizable as synthetic reagents for nucleophilic introduction of acyl group have been so far limited. Recently, we have reported[3] a new synthesis of N-substituted organo(silyliminomethyl)stannanes by palladium(0)-catalyzed reaction of isocyanide with organosilylstannanes. Herein we wish to report that ((2,6-xylylimino)(trialkylsilyl)methyl)stannane is selectively transmetallated at −78 °C with *n*-butyllithium to generate in situ ((2,6-xylylimino)(trialkylsilyl)methyl)lithium, which serves as a versatile acylmetal equivalent reacting with various electrophiles. Of special interest is that the reaction of ((2,6-xylylimino)(trialkylsilyl)-methyl)lithium with carbonyl compounds makes it possible to introduce successively a second electrophile on the imino carbon with concurrent Brook-type migration of the trialkylsilyl group from imino carbon to oxygen.

A dark brown solution of ((2,6-xylylimino)(trialkylsilyl)-methyl)lithium **2**, which is prepared in THF at −78 °C by treatment of ((2,6-xylylimino)(trialkylsilyl)methyl)trialkylstannane **1** with *n*-butyllithium (Scheme I), reacted immediately with a variety of electrophiles (MeOH, Me_3SiCl, EtBr, *n*-BuBr) to give

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