

Finally, these results provide strong evidence for the structure of the intermediate carbonium ion. In the norbornyl system evidence has been presented in support of open, classical ions at the expense of nonclassical, σ -bridged intermediates.^{3,8} Our results are inconsistent with a nonclassical carbonium ion intermediate and can only be accommodated either (1) by open, classical intermediates in which product formation is determined by steric and possibly torsional effects,⁹ or (2) by a concerted hydrogen migration whose driving force is greater than that for bridging.¹⁰

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(8) (a) H. C. Brown and K.-T. Liu, *J. Am. Chem. Soc.*, **89**, 3898, 3900 (1967); (b) P. von R. Schleyer, *ibid.*, **89**, 3901 (1967).

(9) P. von R. Schleyer, *ibid.*, **89**, 699, 701 (1967).

(10) We wish to express appreciation to a referee for several helpful suggestions.

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Conjugated Acetylenic Ketones. 2-Cyclooctynone¹

Sir:

We have found that conjugated acetylenic ketones can be prepared in excellent yield by the reaction of β -bromo α,β -unsaturated ketones with mild base. The reaction is very much more facile than might have been anticipated and provides a fine method for the preparation of these interesting compounds from readily accessible starting materials.²

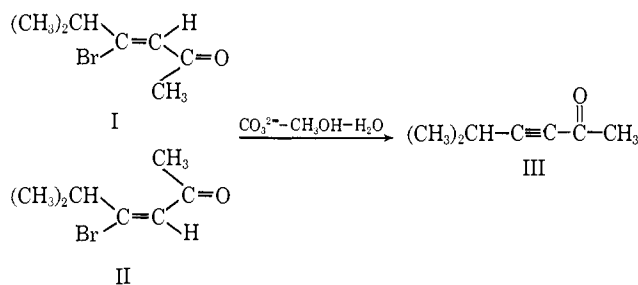
Both *trans*- (I) and *cis*-5-methyl-4-bromo-3-hexen-2-one (II)³ react readily with 0.13 *M* potassium carbonate in aqueous methanol (1:2) or sodium phenoxide in aqueous acetone (1:4) at room temperature to give 5-methyl-3-hexyn-2-one (III). Reaction of 10 mmoles of the *trans* isomer with an equal amount of the base is complete within 2 hr and affords the acetylenic ketone in 87% isolated yield even on this small scale. The reaction is very fast; the first half-life is passed within 5 min. Reaction of the *cis* isomer is about an order of magnitude slower, but the desired product is still obtained in good yield. Similarly, *trans*-4-bromo-3-penten-2-one and *cis*-4-bromo-3-buten-2-one have

(1) The National Science Foundation and the National Institutes of Health contributed generously to the support of this work.

(2) Many of the methods for the preparation of β -chlorovinyl ketones discussed in the review article of A. E. Pohland and W. R. Benson, *Chem. Rev.*, **66**, 161 (1966), are applicable to the synthesis of the corresponding bromo compounds. In some cases the chloro compounds might suffice.

(3) The *cis-trans* designation applies to the geometry of the carbon substituents about the ethylenic bond except for *cis*-4-bromo-3-buten-2-one in which the carbon chain is not long enough. In this one case, the prefix relates the bromo and acetyl groups.

been converted into the corresponding acetylenic ketones.



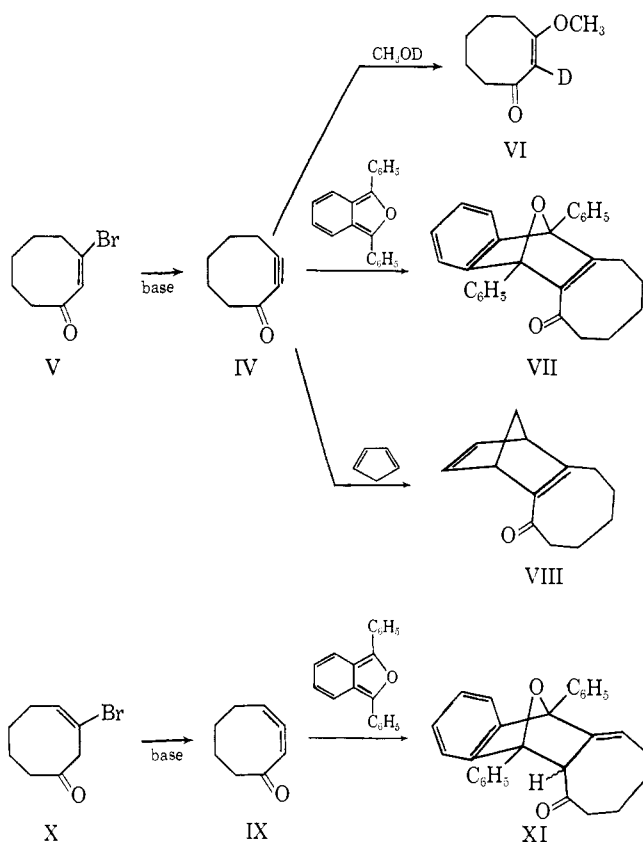
Little is known about the mechanism of elimination reactions from π -bonded systems activated by strong electron-withdrawing groups. It is clear that neither the β,γ -olefinic isomer of the starting bromo enone nor the allene isomer of the product acetylene is an intermediate in the reactions reported here; β -bromo β,γ -enones form conjugated allenyl ketones, and these, in turn, add methanol to give β -methoxy β,γ -enones. For the isomeric pairs of β -bromo α,β -enones we have examined, *trans* elimination is faster than *cis* elimination. This is in accord with previous work on elimination reactions from other olefinic systems.⁴ We have shown that elimination of hydrogen bromide from compound II is much faster than exchange of the α -vinyl hydrogen with deuterium from the solvent. Thus, the elimination reaction is either concerted or the intermediate α -vinyl anion collapses with expulsion of bromide ion faster than reprotonation can occur. It is a moot point as to whether the conjugated π system of the α,β -unsaturated ketone is maintained throughout the reaction or is interrupted to allow the transition state to assume a geometry similar to that of an allenolate anion.

The ease of these elimination reactions across vinylic systems is really quite remarkable. A good case in point is the ready generation of 2-cyclooctynone (IV), a very strained system, by the reaction of 3-bromo-2-cyclooctenone (V) with base. This cyclic, acetylenic ketone is very reactive; it cannot be isolated, but its formation can be demonstrated easily. Reaction of V with potassium carbonate in deuterated aqueous methanol leads to an excellent yield of 3-methoxy-2-cyclooctenone (VI) in which better than 90% of the vinyl hydrogen is heavy. No exchange of the vinyl hydrogen in reisolated, unreacted starting material can be detected, nor, under the conditions of the reaction, is the vinyl hydrogen of light 3-methoxy-2-cyclooctenone exchangeable. Hence, the majority of the reaction product can be accounted for by the addition of deuteriomethanol to 2-cyclooctynone. More direct evidence for the formation of 2-cyclooctynone has been secured from Diels-Alder trapping experiments. Reaction of 3-bromo-2-cyclooctenone with base in non-hydroxylic solvents in the presence of 1,3-diphenylisobenzofuran or cyclopentadiene gives, respectively, 80 and 50% isolated yield of the Diels-Alder adducts VII and VIII of these dienes to 2-cyclooctynone.⁵

(4) S. I. Miller and R. M. Noyes, *J. Am. Chem. Soc.*, **74**, 629 (1952); S. J. Cristol and A. Begoon, *ibid.*, **74**, 5025 (1952); W. E. Truce in "Organic Sulfur Compounds," Vol. 1, N. Kharash, Ed., Pergamon Press, London, 1961, p 112; J. C. Craig and M. Moyle, *J. Chem. Soc.*, 3712 (1963).

(5) Neither diene reacts with 3-bromo-2-cyclooctenone.

2,3-Cyclooctadienone (IX) is not an intermediate in these reactions. We have prepared this interesting cyclic allene by reaction of 3-bromo-3-cyclooctenone (X) with base; it reacts with 1,3-diphenylisobenzofuran to give the two epimers of the expected Diels-Alder adduct XI, but none of VII.

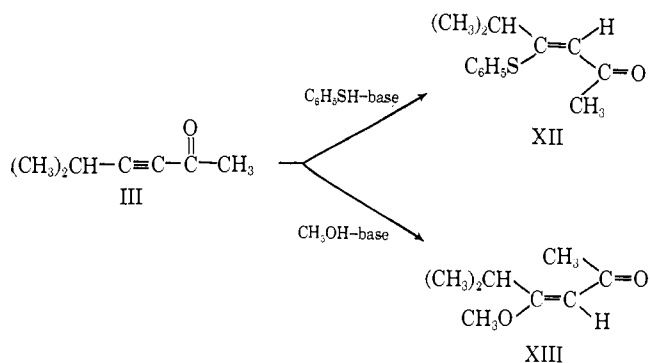


The literature is rich with uses of conjugated acetylenic carbonyl compounds. Nucleophilic additions to the triple bond are of particular value. Most such reactions give *trans*-added products.⁶ For example, the acetylenic ketone III reacts with sodium thiophenoxide in aqueous solvents to give the *trans*- β -thiophenoxy α,β -unsaturated ketone XII. It has been reported that primary and secondary amines add *cis* to activated triple bonds; it has been proposed that the proton carried into the reaction by the amine is transferred specifically to the α -vinyl carbon.⁷ We have found, however, that *cis* addition to conjugated acetylenic carbonyl systems is not restricted to the addition of amines. The base-catalyzed addition of methanol to the acetylenic ketones we have studied takes the same course. For example, reaction of compound III with aqueous methanolic potassium carbonate gives only (by nmr) the *cis*-added *cis*-methoxy α,β -unsaturated ketone XIII. This is known to be the kinetically controlled product as the *trans* isomer of XIII is not isomerized under the reaction conditions. Much remains to be done before the factors that control the

(6) E. Winterfeldt, *Angew. Chem.*, **79**, 389 (1967); W. E. Truce and J. A. Simms, *J. Am. Chem. Soc.*, **78**, 2756 (1956).

(7) E. Winterfeldt and H. Preuss, *Ber.*, **99**, 450 (1966); R. Huisgen, H. Herbig, A. Siegl, and H. Huber, *ibid.*, **99**, 2526 (1966); R. Huisgen, B. Giese, and H. Huber, *Tetrahedron Letters*, 1883 (1967); B. Giese and R. Huisgen, *ibid.*, 1889 (1967). Compare W. E. Truce and D. G. Brady, *J. Org. Chem.*, **31**, 3545 (1966).

stereochemistry of such addition reactions are understood.



(8) Alfred P. Sloan Foundation Research Fellow.

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The Synthesis of a Stable Complex of a Macrocycle and a Threaded Chain

Sir:

Frisch and Wasserman¹ have commented on the expected stability of threaded molecular systems of the type **1** in which bulky groups A prevent the extrusion of a threaded chain B from a macrocycle C. We have synthesized substance **2** belonging to this novel system as described below. Similar methods may be applicable to the synthesis of catenanes¹ and other threaded compounds.

Reaction of 2-hydroxycyclotriacontanone (**3**) with succinic anhydride in pyridine gave the hemisuccinate ester **4**, mp 81–84° (methyl ester molecular ion 564 mass units) which was coupled, *via* the sodium salt, with Merrifield's peptide resin,² forming the resin adduct **5**. Treatment of a column of this resin-bound macrocycle with a solution of decane-1,10-diol and triphenylmethyl chloride in a mixture of pyridine, dimethylformamide, and toluene gave the ether **7** and only traces of the threaded complex **6**. The total yield of this complex was then improved by numerous repetitions of the process. After 70 treatments the column was extracted free of reagents and other soluble materials and the reaction products were hydrolyzed from the resin, by refluxing with sodium bicarbonate in methanol, yielding a mixture containing 6% of complex **2** which was readily purified by chromatography. Complex **2** was an oil, stable at temperatures up to 200°; the infrared spectrum [ν_{\max} 3440 (OH...O), 1710 (CO), 1070 (CH₂O-), 740 and 705 cm⁻¹ (monosubstituted phenyl)] was very similar to that of a mixture of the ether **7** and acyloin **3** although chromatography demonstrated that there was no contamination by the latter two compounds.

(1) H. L. Frisch and E. Wasserman, *J. Am. Chem. Soc.*, **83**, 3789 (1961). A rational synthesis of a member of this system has been mentioned in a preliminary note: G. Schill and H. Zollenkopf, *Angew. Chem.*, **79**, 149 (1967).

(2) R. B. Merrifield, *J. Am. Chem. Soc.*, **85**, 2149 (1963).