Table 11. Catalytic Constants for the Chloroacetate Catalyzed Hydrolysis of 2,2,2-Trifluoro-*N*-(3-methyl-2-cyclohexenylidene)ethylamine at 25.0 ± 0.1°

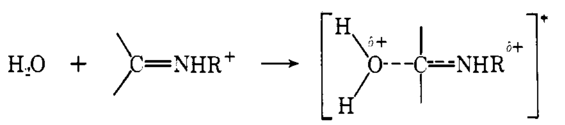
Solvent	k^{B} (M^{-1} sec^{-1})[a]	Buffer ratio[b]
H_2O[c]	$4.17 \pm 0.42 \times 10^{-4}$	2:1
	$5.78 \pm 1.16 \times 10^{-4}$	1:1
	$5.90 \pm 0.25 \times 10^{-4}$	1:4
50% dioxane[d]	$2.19 \pm 0.96 \times 10^{-2}$	2:1
	$2.20 \pm 0.15 \times 10^{-2}$	1:1
	$2.11 \pm 0.05 \times 10^{-2}$	1:4
70% dioxane[e]	$1.34 \pm 0.02 \times 10^{-1}$	2:1
	$1.26 \pm 0.13 \times 10^{-1}$[f]	1:1
	$1.26 \pm 0.13 \times 10^{-1}$[f]	1:4

[a] Rate constant for general base catalyzed attack of water on **1**H$^+$. [b] Acid/base. [c] μ = 1.0 (NaCl). [d] μ = 0.5 (NaCl). [e] μ = 0.3 (NaCl). [f] Calculated by dividing the observed rate constant for chloroacetate catalyzed hydrolysis by the percent of protonated **1**. $[1H^+]/([1] + [1H^+]) = 0.88$ (1:1 buffer) and 0.51 (1:4 buffer).

II).[20] Although chloroacetate is only feebly catalytic in water ($k_b = 5.28 \times 10^{-4}$ M^{-1} sec^{-1}), it is a powerful catalyst in 70% dioxane ($k_b = 1.29 \times 10^{-1}$ M^{-1} sec^{-1}). The effect of changing the solvent from pure water to 70% dioxane is to increase the rate constant for the chloroacetate catalyzed attack of water on **1H$^+$** by almost 250-fold whereas the corresponding rate increase produced by this solvent change for direct water attack is only 11-fold.

Although both chloroacetate and added dioxane accelerate the hydrolysis reaction individually, a combination of a lowered solvent polarity and addition of the general base has an effect much greater than expected on the basis of the accelerations observed for each effect separately. A comparison of the first-order rate constant extrapolated to 1 *M* chloroacetate in 70% dioxane (1.29×10^{-1} sec^{-1}) with the rate constant in pure water-HCl (3.55×10^{-4} sec^{-1}) reveals a rate enhancement of 350-fold. If both the solvent effect (11-fold) and the effect of general base catalysis (2.5-fold) were acting independently, one would predict a rate increase of 28-fold. Clearly, the total observed rate enhancement is substantially greater than the sum of the two individual effects.

A look at the probable transition states for these two processes suggests an explanation for this synergism. Attack by water on the protonated Schiff base causes a delocalization of the positive charge in the transition state, resulting in the observed rate increase as the solvent polarity is lowered (eq 2).[22] General base catalysis by the negatively charged carboxyl group, on the other hand, involves charge destruction rather than simply charge dispersal (eq 3). This process is expected to show a much greater solvent dependence than that of eq 2.[22] It is tempting to speculate that many enzymes which function via Schiff base intermediates use a combination of general base catalysis and an apolar active site to facilitate the formation and hydrolysis of these imines. It is also possible that some of the large rate enhancements of enzymatic reactions may be due in part to synergistic effects.



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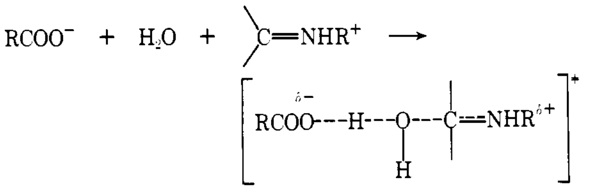

(3)

Acknowledgment. We wish to thank Professor V. P. Vitullo for helpful discussions concerning this work. Financial support from the National Insitute of Health (GM 20188) is gratefully acknowledged.

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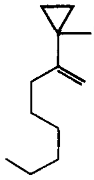
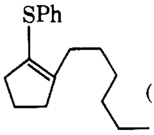
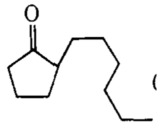
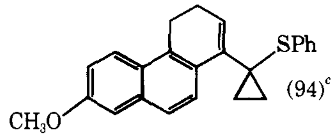
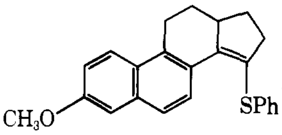
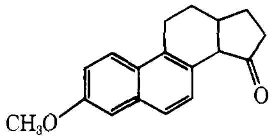
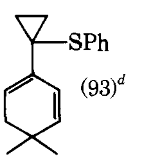
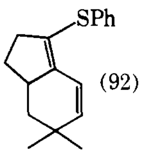
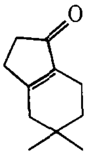
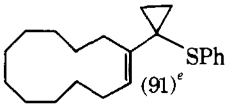
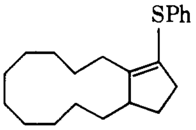
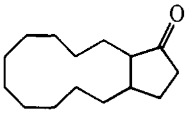
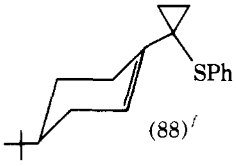
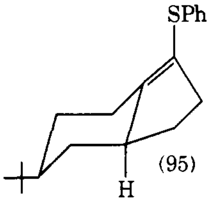
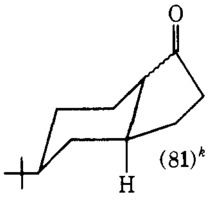
New Synthetic Methods. A Stereocontrolled Approach to Cyclopentane Annelation

Sir:

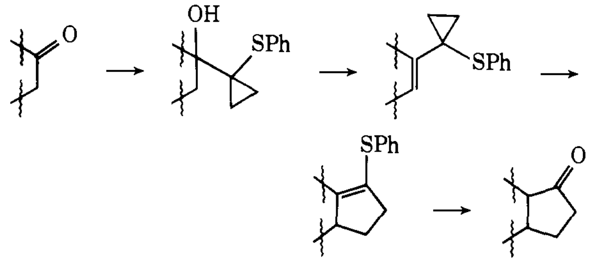
The occurrence of five-membered rings in an increasing number of natural products of biological importance has stimulated the development of a variety of new methods for the synthesis of cyclopentane rings.[1,2] We recently developed a method for preparing masked cyclopentanone systems utilizing the base opening of oxaspiropentanes to form siloxyvinylcyclopropanes followed by thermolysis.[1a] The limitations of this method appeared to be the inability to use α,β-unsaturated ketones as precursors and the poor yields of siloxyvinylcyclopropanes obtained from conformationally rigid six-membered rings. We wish to report (1) a method using the recently developed reagent 1-lithiocyclopropyl phenyl sulfide[3] for cyclopentanone formation which overcomes the limitations of the earlier method, (2) the stereochemistry of the migration of the vinylcyclopropane rearrangement, and (3) an interesting dichotomy in the reaction in the gas phase vs. the condensed phase.

Table I. Cyclopentanone Annelations[a]

Entry	Olefin (% yield)	Cyclopentene (% yield)	Cyclopentanone (% yield)
1	 (93)[b]	 (93)	 (100)[g]
2	 (94)[c]	 (94)	 (73)[h]
3	 (93)[d]	 (92)	 (75)[i,l]
4	 (91)[e]	 (92)	 (71)[j]
5	 (88)[f] **2**	 (95) **3**	 (81)[k] **4**

[a] All adducts of 1-lithiocyclopropyl phenyl sulfide to the ketone were prepared by the method of ref 3: entry 1, 87%; entry 2, 96%; entry 3, 86%; entry 4, 94%; entry 5, see ref 3. For dehydrations see text. [b] NMR: δ 4.8, bs, 2 H; δ 1.1, s, 4 H. [c] NMR: δ 5.65, t, $J = 6$ Hz, 1 H; δ 3.85, s, 3 H; mp 151–153°. [d] NMR: δ 5.6, AB quartet, $J = 10$ Hz, 2 H; δ 5.4, bs, 1 H; δ 2.0, d, $J = 4$ Hz, 2 H. [e] NMR: δ 5.2, t, $J = 8$ Hz, 1 H. [f] NMR: δ 5.4, bs, 1 H; δ 0.95, s, 4 H; δ 0.85, s, 9 H. [g] Ir: 1735 cm^{-1}. [h] Ir: 1740 cm^{-1}. [i] Ir: 1708, 1665 cm^{-1}. [j] Ir: 1745 cm^{-1}. [k] Ir: 1745 cm^{-1}; mp 64–65°. [l] For a similar isomerization of an exocyclic cyclopentenone to an endocyclic isomer see M. P. L. Caton, E. C. J. Coffee, T. Parker, and G. L. Watkins, *Synth. Commun.*, 4, 303 (1974).

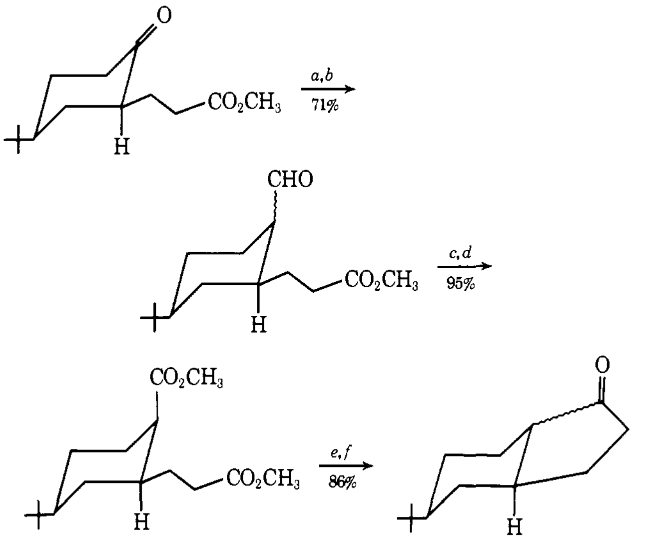
The overall transformation is outlined in eq 1. Dehydration of the hydroxy sulfides[3] without complications arising from ring expansion was achieved with thionyl chloride in pyridine at 0° in yields of 85-95%. In the case of the adduct of 4,4-dimethylcyclohex-2-en-1-one, use of the Burgess reagent[4a] in refluxing benzene for 6 hr effected dehydration in 93% yield.[4b] Thermolysis of the vinylcyclopropanes by passing a hexane solution through a conditioned[5] hot tube packed with glass helices at 350° with a contact time of 12-15 sec led to the smooth rearrangement to the enol thio esters listed in Table I.[6] Rearrangement of the tricyclic compound **1** (Table I, entry 2) to generate the steroid skeleton was performed in toluene in a heavy-walled sealed tube at 250° for 2 hr. Hydrolysis ($TiCl_4$, HOAc, H_2O, room temperature)[7] of the enol thio ethers led to the cyclopentanones listed in Table I.[6] The regioselectivity of this annelation process parallels that based upon the oxaspiropentane intermediates.[1a]


(1)

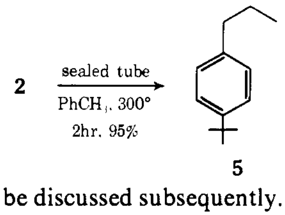
The stereochemistry at the migration terminus in a six-membered ring in the vinylcyclopropane rearrangement was determined to be equatorial in the case of **2** (see Table I) which contrasts with the results obtained in Claisen rearrangements.[8] Examination of molecular models reveals that formation of an axial bond would force the six-membered ring into a twist boat conformation, whereas equatorial bond formation permits generation of the preferred chair conformation. The stereochemistry of **3** was determined by hydrolysis to **4** and comparison of the latter (mixture melting point, chromatographic behavior, spectroscopic properties) with that produced via an independent route (see Scheme I). The high stereoselectivity of this annelation enhances the utility of this approach.[9]

Initial attempts at thermolysis of the vinylcyclopropanes were done in toluene or benzene solution in sealed tubes under vacuum at 300° for 1 hr. Unidentifiable product mixtures were obtained in most cases (except Table I, entries 2 and 5). An interesting dichotomy was seen in the case of compound **2**. Sealed tube thermolysis led exclusively to 4-*tert*-butyl-1-*n*-propylbenzene (**5**), whereas hot tube thermolysis led exclusively to compound **3**. Whereas the reasons for this difference can only be speculated upon, one possible explanation relates to the fate of the initially formed (and unproductive in terms of the desired reaction) transoid di-

Scheme I

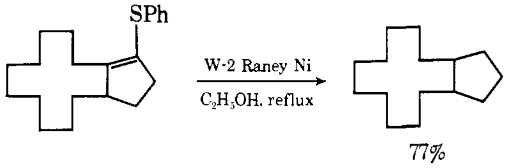


^{a}Ph$_3$$^+PCH_2OCH_3Cl^-$, n-C$_4H_9Li, Et_2$O, reflux. ^{b}HClO$_4$, H$_2O, CH_2Cl_2$, reflux. ^{c}CrO$_3$, (CH$_3$)$_2CO, H_2O, H_2SO_4$, room temperature. ^{d}CH$_2$N$_2$, Et$_2$O, room temperature. ^{e}NaH, CH$_3$OH, Et$_2$O, reflux. ^{f}NaCl, H$_2$O, DMSO, 160°.



radical and will be discussed subsequently.

Other advantages of this new approach in addition to those mentioned in the introduction include the inexpensive cost and large scale availability of cyclopropylphenyl sulfide and the ease of handling the intermediates along the path. It furthermore expands the synthetic flexibility since the intermediate enol thioethers can in principle be desulfurized[10] to yield regiospecifically generated cyclopentenes, hydrolyzed to give regiospecifically generated α-bromo ketones[11] and therefore regiospecifically generated cyclopentenones or hydrogenated (eq 2) to the cyclopentane.



(2)

Acknowledgment. We wish to thank the National Institutes of Health and the National Science Foundation for their generous support of our programs.

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(4) (a) E. M. Burgess, H. R. Penton, and E. A. Taylor, *J. Org. Chem.*, **38**, 26 (1973). (b) Choice of the dehydrating method is important since dehydration accompanied with rearrangement to a cyclobutene thioether[3b] can become the major, if not exclusive, course. In one case, the use of a xanthate pyrolysis at 150° in HMPA was the preferred method.

(5) (a) Conditioning of the column consisted of treating the preheated (250°) column with *O,N*-bistrimethylsilylacetamide followed by hexane. (b) Conditioning of the sealed tubes involved drying under N$_2$ at 120° for 12 hr and washing with *O,N*-bistrimethylsilylacetamide followed by benzene. Pyrolyses in sealed tubes were performed in vacuo at ~0.1 mm.

(6) All new compounds had spectral properties and analytical data in complete accord with the assigned structure.

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Received July 1, 1975

Resonance Raman Spectroelectrochemistry. IV. The Oxygen Decay Chemistry of the Tetracyanoquinodimethane Dianion

Sir:

Currently there is a high level of interest in the charge-transfer salts of tetracyanoquinodimethane (TCNQ) with certain organic donor molecules such as tetrathiofulvalene (TTF) which display large electrical conductivities and "metallic" properties over a wide temperature range.[1] A variety of molecular orbital calculations have been carried out on TCNQ, TCNQ$\cdot^-$, TCNQ^{2-}, (TCNQ)$_2$, (TCNQ$\cdot^-$)$_2$, poly(TCNQ), poly(TCNQ$\cdot^-$), and poly(TCNQ^{2-}) as well as the corresponding TTF moieties in an effort to develop a more detailed picture of the electronic structure of these materials.[2-5] In order to evaluate and provide experimental support for these increasingly more sophisticated calculations, it is necessary to obtain reliable measurements of both ground and excited state properties of monomeric TCNQ, TTF, and their ions as well as the corresponding dimers. Electronic absorption spectroscopy[6,7] and electron spin resonance spectroscopy[8] have been widely used to provide such data. Recently vibrational spectroscopy has been recognized as an important tool for the characterization of charge-transfer solids.[9-11]

In a recent paper we reported the successful interfacing of electrochemical species generation with vibrational spectroscopic observation based on the resonance Raman (RR) effect to produce the hybrid technique of resonance Raman spectroelectrochemistry (RRSE).[12] Using tetracyanoethylene (TCNE) as a test system, we demonstrated that RRSE was an effective means of measuring the ground state vibrational frequencies of the totally symmetric bond stretching modes of TCNE$\cdot^-$ in a minimally perturbing environment. Comparison of the TCNE$\cdot^-$ vibrational frequencies measured by RR scattering spectroscopy with the corresponding TCNE vibrational frequencies measured by normal Raman (NR) spectroscopy yielded the electron transfer induced vibrational shifts which were then compared with the appro-