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Generation of Cycloalkynes by Hydro-Iodonio-Elimination of Vinyl Iodonium Salts

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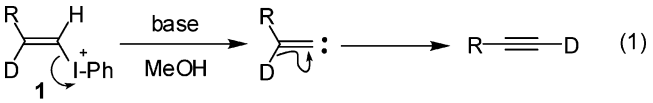
ABSTRACT

Cyclohexynes can be generated efficiently from 1-cyclohexenyliodonium salts with acetate or other bases via the E2 and E1 mechanism. The observed regioselectivity of nucleophilic addition to substituted cyclohexynes conforms to the LUMO populations: the less deformed acetylenic carbon is more electrophilic. Cycloheptyne can form by the E1-type elimination via 1,2-rearrangement from cyclohexylidenemethyliodonium salt under very weakly basic conditions.

Introduction

Vinyl iodonium salts are a class of very reactive compounds that exhibit a variety of reactivities and have been subjects of extensive reviews.[1] High reactivity of vinyl iodonium salts arises from the highly electron-withdrawing ability of the positive iodine group as well as the high nucleofugality (leaving ability) of the iodonio group. The Hammett substituent constant σ_m is reported to be 1.35 for the PhI^+ group,[2] while the nucleofugality is evaluated to be 10^{12} times as great as for iodine itself.[3] Because of their electrophilic nature, the main reactions of vinyl iodonium salts are those with nucleophiles and bases. In our previous accounts,[1d,f] attention was focused on mechanisms of nucleophilic substitution at the vinylic carbon: S_NV1 via a vinylic cation intermediate[1d] and two S_N2 reactions via in-plane nucleophilic attack on the σ^* orbital ($S_NV\sigma$) and out-of-plane attack on the π^* orbital ($S_NV\pi$).[1f]

Base-induced reactions involve α- and β-hydro-iodonio-elimination. α-Elimination of 1-alkenyliodonium salts **1** is readily effected by a wide range of bases to give alkylidenecarbenes as shown in eq 1 with the deuterated substrate. The bases include alkoxides, amines, carboxylates, and fluoride, as well as typical nucleophiles such as cyanide and azide, as listed below eq 1.[4] These bases are categorized as those of pK_{BH}^+ (pK_a of the conjugate acid) > 0.

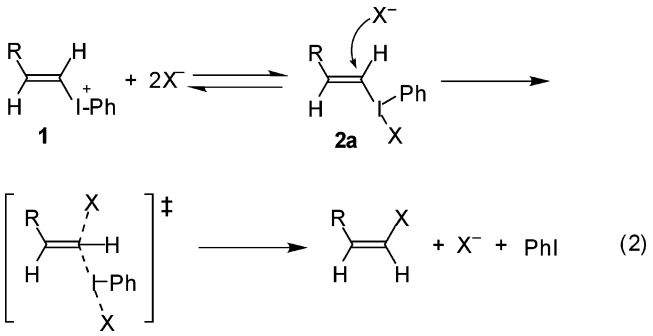


(1)

base: MeONa, Et_3N, pyridine, Na_2CO_3, KCN, NaN_3, $NaNO_2$, $NaHPO_4$, $FNBu_4$, $MeCO_2Na$, HCO_2Na, Cl_2CHCO_2Na

The nature and consequences of alkylidenecarbenes generated from vinylic iodonium salts have been reviewed.[1c,h] Depending on the structure of the carbene and reaction conditions, the unsaturated carbenes undergo 1,2-rearrangement to alkyne (eq 1),[4−7] intramolecular insertion to give cyclopentene and related derivatives,[5,8] insertion to the solvent,[8] and trapping with alkenes to give methylenecyclopropanes.[9] Cycloalkylidenecarbene can provide a ring-expanded cycloalkyne via 1,2-rearrangement, so-called Fritsch−Buttenberg−Wiechell (FBW) rearrangement,[10] as will be discussed below.

Less basic ($pK_{BH}^+ < 0$) but still nucleophilic reagents such as chloride and bromide ions induce S_N2 reactions, $S_NV\sigma$ and $S_NV\pi$, depending on the structure of the vinylic iodonium salts and reaction conditions.[1f] The nucleophile is first coordinated at the iodine to form a hypervalent λ^3-iodane **2**, and simple 1-alkenyl derivatives undergo bimolecular in-plane attack to lead to the product of inversion as shown in eq 2 ($S_NV\sigma$).[6,11] However, if this reaction is retarded by, e.g., the β-halo group[12] or the cyclic structure, the $S_NV\pi$ reaction shows up to lead to retention of configuration; the reaction occurs intramolecularly within the λ^3-iodane intermediate **2b** (λ^3-iodane is in equilibrium among conformers such as **2a** and **2b**) in a fashion of ligand coupling (eq 3).[1f,11a,12,13]



(2)

An intramolecular β-elimination of acyclic 1-alkenyliodonium salts such as **1** can be observed as a side reaction of the $S_NV\sigma$ reaction with halides. The only example where this elimination becomes major is the halide reaction of (*E*)-3,3-dimethyl-1-butenyl(phenyl)-iodonium tetrafluoroborate (**4**) (eq 4).[11b]

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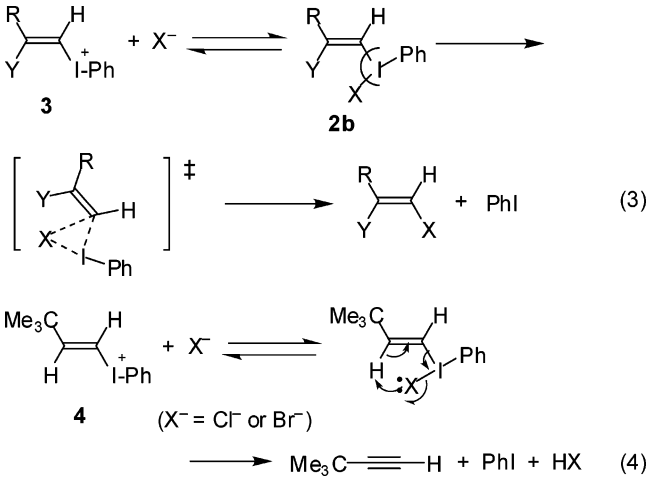
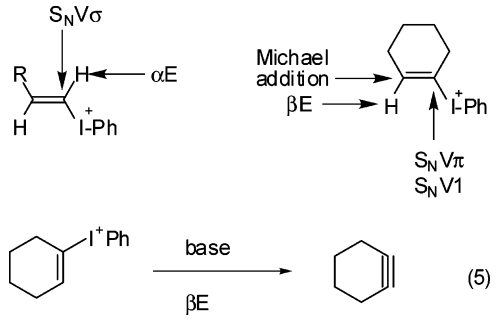
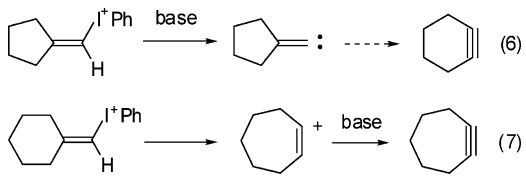


The most favorable reactions of 1-alkenyliodonium salts with bases/nucleophiles are in general α-elimination (αE) and $S_NV\sigma$ reaction at the α position because of the strong activation with the iodonio group. To observe reactions at the β position, the favorable reactions at the α position must be inhibited, and cyclic vinyl iodonium salts were employed for investigation of possible reactions at the β position. During these investigations, cyclohexyne was successfully generated from the iodonium salt under mild basic conditions (eq 5).

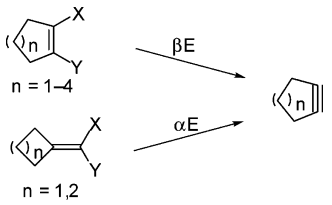


Cycloalkylidenemethyliodonium salts can in principle provide the ring-expanded cycloalkynes via α-elimination, followed by the FBW rearrangement (eq 6). However, this reaction was not efficient, and the E1-type reaction via the ring-expanded vinylic cation could afford the cycloalkyne by tuning the basicity/nucleophilicity of the reaction media. Cycloheptyne could be generated efficiently by this method (eq 7).



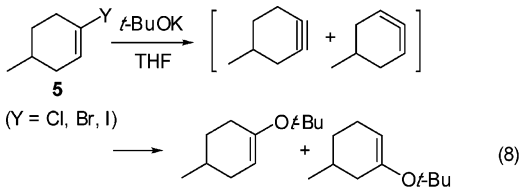
The chemistry of small-ring cycloalkynes has been a focus of interest for more than a century and has been a topic of many reviews.[14] Angle-strained cycloalkynes were in general generated under strongly basic conditions by 1,2-elimination of cycloalkene precursors such as 1,2-dihalocycloakene and 1-halocycloalkene and also by the FBW rearrangement of cycloalkylidenecarbenes/carbenoids

Scheme 1



(Scheme 1). Cyclohexyne is only isolable in matrixes at 77 K,[15] while cycloheptyne has some lifetime in solution at −25 °C.[16] They can be generated in solution as transient species but readily undergo oligomerization and reactions with nucleophiles.[14] A typical reaction to generate cyclohexyne is given in eq 8. In this reaction, main final products are regioisomers resulting from nucleophilic addition to the intermediate products of elimination.[17] Under these strongly basic reaction conditions, cyclohexa-1,2-diene was formed in addition to cyclohexyne.[18] Cycloalkynes are known to isomerize to the 1,2-dienes under basic conditions. The ratio of the two regioisomeric substitution products formed via the elimination−addition pathways (eq 8) was found to range from 98:2 to 56:44, depending on the reaction conditions,[17] probably because of the changing ratio of the cyclohexyne/cyclohexa-1,2-diene intermediates. The regioselectivity of the nucleophilic reaction of cyclohexyne itself is unknown for this reason. Thus, a mild and general method for selective generation of cycloalkyne was awaited to permit the study of its reactivity.

In the present Account, we summarize efficient and mild generation of cyclohexynes and cycloheptynes via the two types of reactions of iodonium salts. The regioselectivity of nucleophilic addition to substituted cyclohexynes will also be considered.



β-Elimination of Cyclohexenyl Iodonium Salts

1-Cyclohexenyl(aryl)iodonium tetrafluoroborate (**6**) undergoes S_NV1 solvolysis in hydroxylic solvents,[3] while reactions of the substituted derivative **6** with bromide and thiolate in chloroform gives the *ipso*[19] substitution products probably via the $S_NV\pi$ (ligand coupling) mechanism.[1f,12] In contrast, the reaction of the 4-substituted derivatives **6** with tetrabutylammonium acetate resulted in two isomeric substitution products, *ipso* and *cine*[19] acetates (**8** and **9**), in 50−80% yield (Scheme 2).[20] The same products **8** and **9** were obtained in a similar ratio in the reaction of the isomeric 5-substituted substrate **7**. The product ratios **8**/**9** obtained from **6** and **7** with various substituents are summarized in Table 1.

When the acetate reaction of **6d** was carried out in the presence of 1 vol % of methanol-*d* as a deuteron source,

Scheme 2

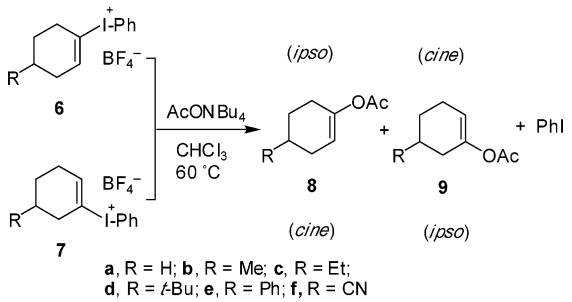
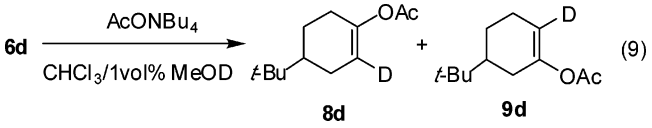


Table 1. Product Ratios 8/9 Observed in the Reactions of Isomeric Iodonium Salts, 6 and 7, with Acetate[a]

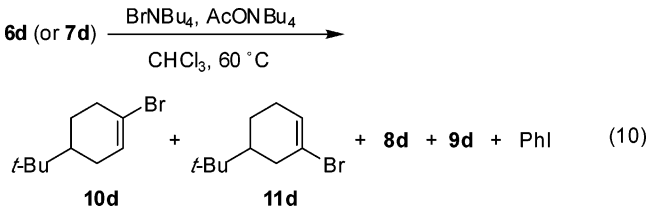
substituent[b]	6	7	substituent[b]	6	7
Me	46:54	39:61	Ph	57:43	49:51
Et	39:61		CN	81:19[c]	
t-Bu	28:72	21:79			

[a] Reactions were carried out at [$AcONBu_4$] = 0.10 M and 60 °C in $CHCl_3$. [b] 4- or 5-Substituent R of **6** or **7**. [c] Obtained from a mixture (61:39) of **6f** and **7f**.

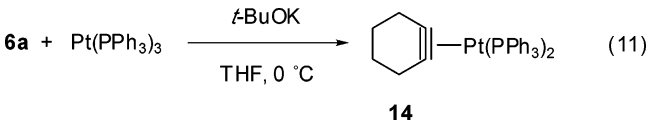
the olefinic position of the acetate products was deuterated by about 70 atom % (eq 9).



Reaction of **6** or **7** in the presence of both acetate and bromide afforded two isomeric *ipso* and *cine* bromide products **10** and **11** as well as the acetate products **8** and **9** (eq 10), although only the *ipso* bromide was formed in the absence of acetate. The product distribution is very much dependent on the concentrations of the two bases/nucleophiles.[20] Illustrative results were obtained at [$BrNBu_4$] = 0.094 M and [$AcONBu_4$] = 0.005−0.007 M, with yields of **10d**, **11d**, **8d**, and **9d** being 23, 27, 6, and 9% from **6d** and 12, 48, 1, and 4% from **7d**, respectively.



These results are expected if the β-elimination of **6** (or **7**) occurs to give cyclohexyne **12** as a common intermediate, and it undergoes nucleophilic addition of acetate or bromide. Cyclohexyne **12** could in fact be trapped very effectively with tetraphenylcyclopentadienone (TPC) (Scheme 3 and Table 2). Other bases such as fluoride and alkoxide are also effective in the β-elimination of **6** (**7**), but amines seem to be less effective. Cyclohexyne (**12a**) could also be trapped as a platinum complex **14** (eq 11).[20b]



Scheme 3

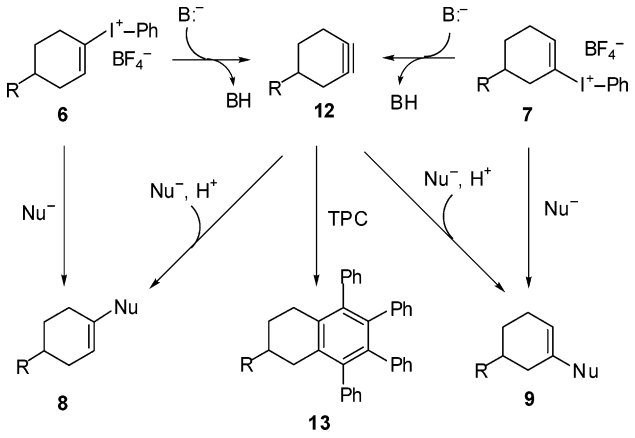


Table 2. Isolated Yields (%) of the Adduct 13 in the Reaction of 6 and 7 in the Presence of TPC[a]

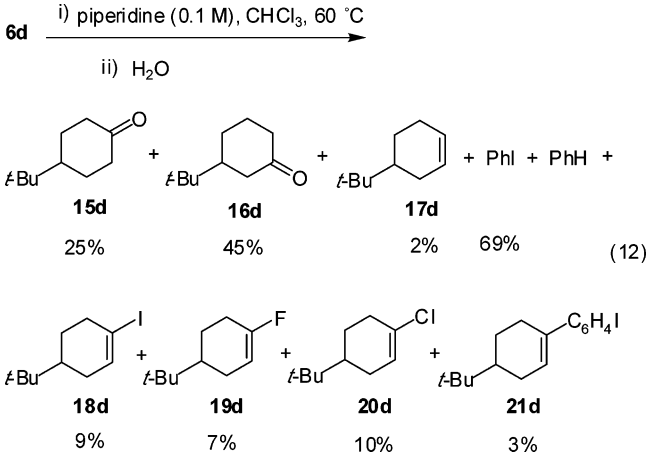
base (concentration, M)	6a	6b	6c	6d	6e	6f[b]	7d
$AcONBu_4$ (0.01)	90	84	86	91	98	64	70
$FNBu_4$ (0.01)	81	100	95	94	98	37	63
MeONa (0.18)[c]				81	87		
piperidine (0.10)				52			
Et_3N (0.10)				29			

[a] Reactions were carried out in chloroform at [**6** (or **7**)] = 3−8 mM, [TPC] = 10 mM, and 60 °C for 1−2 h. [b] A mixture of (61:39) of **6f** and **7f**. [c] In methanol.

Mechanism of Elimination

The trapping experiments showed that amines were unexpectedly much less effective in the hydro-iodonio-elimination reaction than acetate and fluoride. Byproducts observed suggest side reactions because of the cationic intermediates. This was more clearly shown in the product distribution of the reaction of **6d** with piperidine in chloroform in the absence of the trapping agent TPC (eq 12). In addition to hydrolysis products **15d** and **16d** of the expected enamines and the products of homolysis (**17d**, **18d**, and benzene), characteristic products from the intermediate cyclohexenyl cation (**19d**, **20d**, and **21d**) were observed in significant yields. The vinylic cation can react with the counteranion BF_4^- (to give **19d**)[21] and the neutral leaving group, iodobenzene, within an incipient ion−molecule pair (to give **21d**)[3] and can abstract chloride from the solvent $CHCl_3$ (to give **20d**).[21] These observations strongly suggest the intermediacy of cyclohexenyl cation in the amine reaction in chloroform.

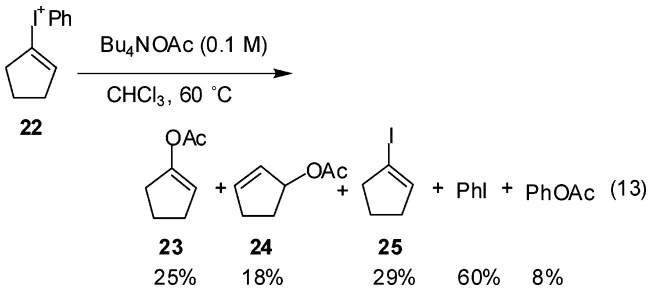
Rates for the acetate and piperidine reactions of **6d** and 2,6,6-trideuterated analogue **6d**-d_3 were measured at 60 °C in chloroform.[20b] Primary kinetic isotope effects k_H/k_D of about 2.5 were observed for the acetate reaction, while the rates for the amine reaction are similar between **6d** and **6d**-d_3 ($k_H/k_D \approx 1.1$). These results are consistent with the E2 mechanism for the former reaction involving rate-determining deprotonation, while the E1 mechanism for the latter with rate-determining formation of the cyclohexenyl cation intermediate. The kinetic suggestions also conform to the product distributions in the respective reactions. If you think of basicities of the amine and acetate from the knowledge of pK_a values of the conjugate acids (about 10 versus 4.76), you may doubt why less basic



acetate induces the E2 reaction but more basic amine allows spontaneous heterolysis of the iodonium ion in the E1 mechanism. The pK_a values mentioned above are those observed in aqueous solution, but those in aprotic solvents are much different from these values. The basicity of an ionic base increases enormously, but that of a neutral base remains essentially unchanged; e.g., pK_a values in DMSO of acetic acid and triethylammonium ion are 12.6 and 9.0, respectively.[22] That is, acetate must be a stronger base than piperidine and triethylamine in chloroform.

Attempts to Generate Cyclopentyne

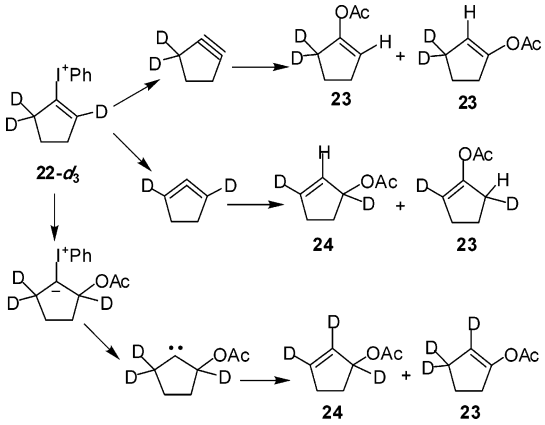
Reaction of 1-cyclopentenyl(phenyl)iodonium tetrafluoroborate (**22**) with acetate was carried out in the same way in chloroform at 60 °C.[23] The cyclopentenyl derivative **22** is much less reactive than the cyclohexenyl substrates, **6** or **7**. The products and their yields obtained in 27 h at [AcONBu$_4$] = 0.10 M are given in eq 13. In addition to vinylic substitution product **23**, allylic acetate **24** was obtained in a significant yield.



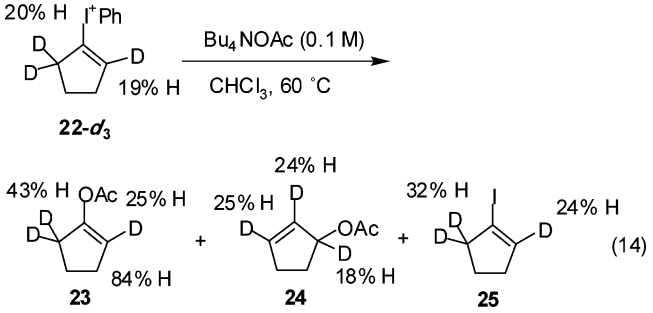
The vinylic product **23** could have been formed via a cyclopentyne intermediate, but how was the allylic product **24** formed? Possible mechanisms for formation of these products are given in Scheme 4 for the reaction of deuterated substrate **22**-d_3. The deuterium distribution from the labeled substrate provides good information on how products are formed. Elimination−addition (EA) mechanisms via cyclopentyne and cyclopenta-1,2-diene can explain the formation of both vinylic and allylic prodcuts **23** and **24**. These mechanisms predict incorporation of a protium in a different position of the product.

The ^{1}H NMR analysis of the acetate products obtained from **22**-d_3 (of about 80% deuterium content) showed

Scheme 4



protium distributions given in eq 14.[23] Both the products **23** and **24** retain the original deuterium essentially without loss, although the deuterium migration took place. The EA mechanism via either cyclopentyne or the 1,2-diene is excluded. The third pathway is possible involving the Michael addition−elimination (AE) via intermediate ylide and carbene followed by a 1,2-hydrogen (deuterium) shift. In this mechanism, all of the labels of the substrate should be retained, and this is the case for the allylic product **24**. The deuterium distribution in the product **23** is different from that expected for the Michael route; this product may be formed mainly via the ligand-coupling mechanism but partially via the Michael AE mechanism.

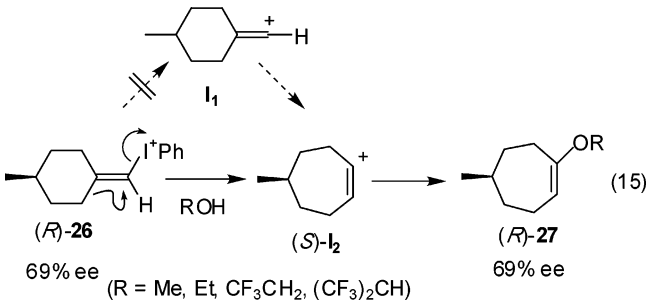


A similar Michael AE mechanism was observed for the reaction of **22** with cyanide ion. This AE mechanism is not limited to the cyclopentenyl system, but the cyanide reaction with cyclohexenyl iodonium salt **6** was found to proceed via this mechanism involving the Michael addition.[23]

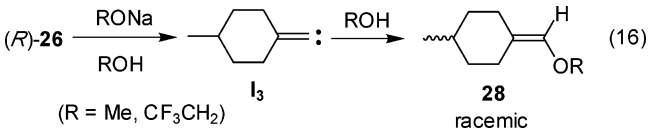
Cycloheptyne Generated from Cyclohexylidenemethyl Iodonium Salt via the E1-Type Mechanism

Cyclohexylidenemethyliodonium salt **26** undergoes ring expansion to give mainly cycloheptenyl products **27** under solvolytic conditions (eq 15).[24] When the chiral substrate (*R*)-**26** was used for the solvolysis, the chirality was completely transferred to the product **27**; i.e., the enatiomeric excess (69% ee) of the optically active (*R*)-**26** was retained in the product (*R*)-**27** (69% ee). This result shows that the 1,2-rearrangement occurs concertedly with the departure of the iodonium leaving group via β-C−C bond

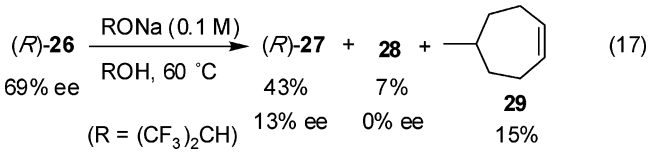
participation from the trans position and is taken as evidence against formation of the primary vinyl cation intermediate ($\mathbf{I}_1$). This observation was found in a wide range of alcohols from methanol to 1,1,1,3,3,3-hexafluoro-2-propanol (HFIP).



In the presence of alkoxide, the product switched to the unrearranged enol ether **28**, which was completely racemized in methanol and 2,2,2-trifluoroethanol (TFE) (eq 16).[25] This is rationalized as a consequence of α-elimination followed by the facile alcohol insertion of the alkylidenecarbene intermediate ($\mathbf{I}_3$).



A different result was obtained in the reaction of (*R*)-**26** in HFIP containing the alkoxide to give largely racemized **27** with accompanying formation of **28** and reduction product **29** (eq 17).[25] Intermediacy of the primary cation $\mathbf{I}_1$ could be suspected in the solvolysis in the highly ionizing solvent as a reason for racemization of the rearranged product **27** as well as the unrearranged one **28**, but this intermediate was excluded in the same solvent in the absence of base.[24] It is less likely in the more basic media.



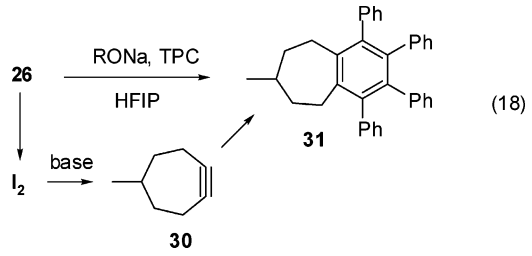
Trapping experiments with TPC under these conditions (in HFIP) show formation of cycloheptyne **30** to give the adduct **31** in more than 60% yields (eq 18, Table 3). Yields of **31** are much smaller in chloroform or TFE containing base. The racemized **27** must be formed via nucleophilic trapping of the intermediate **30**. The cycloheptyne **30** can be derived from the rearranged cation $\mathbf{I}_2$ in a manner of the E1 elimination. Such a reaction does not efficiently occur in TFE or chloroform, but the α-elimination (αE) is

Table 3. Trapping of Cycloheptyne 30 with TPC in the Reaction of 26[a]

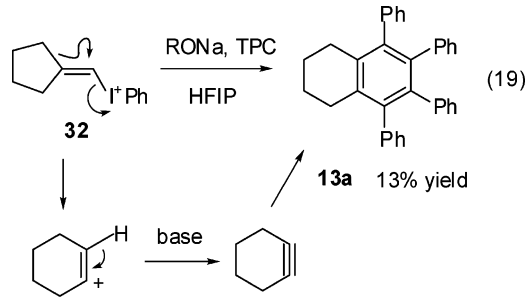
solvent	base	yield of **31** (%)
HFIP	RONa	67
HFIP	Et_3N	62
HFIP/$CHCl_3$ (1:9)	RONa	46
TFE/$CHCl_3$ (9:1)	Et_3N	2
$CHCl_3$[b]	Et_3N	8

[a] At [**26**] = 0.01 M, [TPC] = 0.02 M, [base] = 0.1 M, and 55−60 °C. [b] At [base] = 0.05 M and room temperature.

preferred in these solvents. The reduction product **29** can be derived from **30** under the reaction conditions.[25]



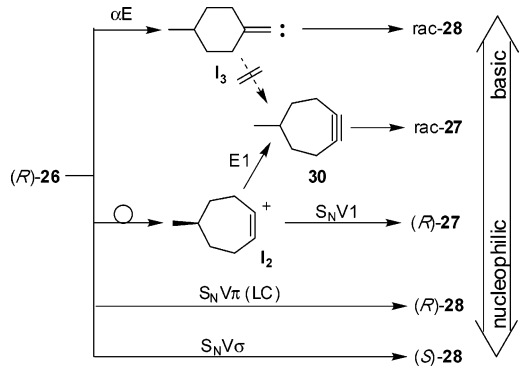
Generation of a smaller ring alkyne, cyclohexyne, via ring expansion of cyclopentylidenemethyliodonium salt **32** was examined in the presence of TPC under the best conditions (in HFIP) for cycloheptyne formation. However, the isolated yield of the adduct **13a** was only 13% (eq 19). The rearrangement of **32** to cyclohex-1-enyl cation must occur less readily than that of **26** to $\mathbf{I}_2$ owing to the higher strain of the smaller ring vinyl cation. Formation and rearrangement of cyclopentylidenecarbene must also be inefficient in HFIP as observed for **26**.



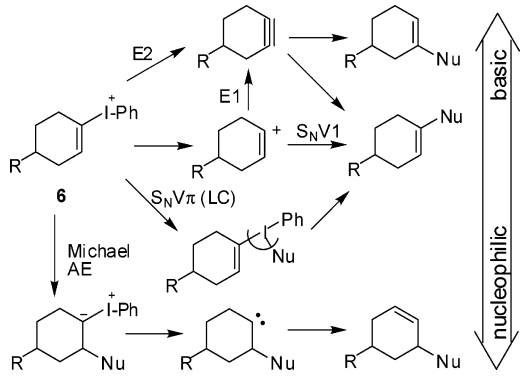
Summary of the Reactions of Iodonium Salts Leading to Cycloalkynes

Possible reactions of cyclohexylidenemethyl iodonium salt **26** in alcohol are summarized in Scheme 5. Nucleophilic and basic reactions compete with each other at each step of the reaction pathway. Stronger nucleophiles and bases induce S_N2 and α-elimination (αE) of **26**, respectively, but 1,2-rearrangement is allowed in poorly reactive media to give the cation $\mathbf{I}_2$. The latter reaction occurs in acidic and neutral alcohols and in HFIP even in the presence of poorly basic alkoxide (the conjugate base of HFIP). The cation $\mathbf{I}_2$ is again subject to competition between nucleophilic and basic reactions leading to the S_N1-type product [(*R*)-**27** from (*R*)-**26**][26] and the E1-type product **30**, re-

Scheme 5



Scheme 6



spectively. The latter reaction is allowed only under very poorly nucleophilic but weakly basic conditions, e.g., HFIP with base. A similar reaction of **26** via **30** was also observed with methanesulfonate in chloroform.[27] Rearrangement of cycloalkylidenecarbenes such as $\mathbf{I}_3$ to cycloalkynes is known,[28] but this reaction was not observed with $\mathbf{I}_3$ in alcoholic solvents.

Similar competition between nucleophilic and basic reactions does occur with cyclohexenyl iodonium salt **6** (Scheme 6). The S_NV1 solvolysis takes place in alcoholic solvents, while the ligand-coupling (LC)-type $S_NV\pi$ reaction, the Michael addition, and β-elimination occur usually in aprotic solvents as well as with strong nucleophiles/bases in alcohol. In aprotic solvents, bases such as acetate, fluoride, and alkoxide induce E2, while amines promote E1 elimination. Reaction with bromide leads to $S_NV\pi$, and that with cyanide leads to the Michael addition−elimination (AE) of cyclohexenyliodonium salt.

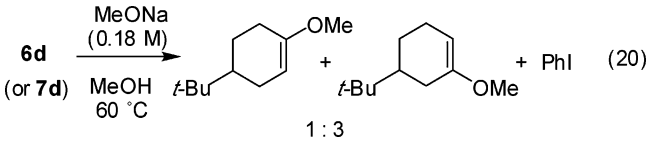
Regioselectivity of Nucleophilic Addition

Regioselectivity of nucleophilic addition to the intermediate cyclohexyne **12** can be discussed from the product ratios of the *ipso* and *cine* substitution (Scheme 2). This selectivity is not much dependent on the identity of the nucleophiles, as is seen in the bromide-trapping results (eq 10), although these values are somewhat disturbed by additional *ipso* product formation via the S_N1 or $S_NV\pi$ route. Similar results are also seen in methoxide substitution in methanol (eq 20) and the piperidine reaction in chloroform (eq 12).

Table 4. LUMO Populations[a] and Bond Angles[b] at the Acetylenic Carbons of Substituted Cyclohexynes Optimized by B3LYP/6-31G(d)

substituent	f_1	f_2	θ_1 (deg)	θ_2 (deg)
H	0.400 37	0.400 37	131.7	131.7
4-Me	0.394 13	0.401 46	130.9	132.0
4-Et	0.394 26	0.403 01	130.6	132.2
4-*t*-Bu	0.387 41	0.407 24	129.5	133.5
4-Ph	0.379 27	0.373 32	131.2	132.1
4-CN	0.407 28	0.375 23	133.4	130.9
3-Me	0.395 43	0.398 84	131.6	132.3
H(4-*t*-Bu)[c]	0.391 00	0.409 50	129.5	133.5

[a] f_1 and f_2 are the LUMO populations at C1 and C2 of the substituted cyclohexyne, respectively. [b] θ_1 and θ_2 are the bond angles at C1 and C2 of the substituted cyclohexyne, respectively. [c] A model calculation on the optimized cyclohexyne ring for 4-*tert*-butylcyclohexyne, but the *tert*-butyl group is replaced with hydrogen.



Thus, the results summarized in Table 1 for the acetate reaction of various substrates provide the first data to show the regioslectivity of nucleophilic addition to substituted cyclohexynes. Similar selectivity of nucleophilic addition to the triple bond was found during the reaction of nucleophilic aromatic substitution via the benzyne intermediate. The selectivity of nucleophilic addition to benzynes was attributed to the inductive effect of the substituents.[14a] The present results for the 4-CN and 4-alkyl derivatives seem to conform to the electronic consideration, but those within alkyl derivatives are difficult to be reconciled with the electronic effects; the σ_I values are similar among alkyl groups,[29] and the position of substitution is rather remote, separated by two bonds from the reaction site. What is the origin of the regioselectivity of nucleophilic addition?

Theoretical calculations were carried out on substituted cyclohexynes at the level of B3LYP/6-31G(d), and the results are summarized in Table 4. The bond angles at the acetylenic carbons are about 130° but dependent on the substituent. The LUMO population at the reaction center must be reflected on the selectivity of the nucleophilic attack. The selectivity values, log(**9**/**8**), for 4-substituted cyclohexynes **12** and the equivalent value for the 3-methyl derivative are plotted against the differences between the LUMO populations at C2 and C1, $(f_2 - f_1)$, in Figure 1. It shows a good correlation between the selectivity and the LUMO populations, including 4-phenyl and 4-cyano derivatives.

If the electronic effects of alkyl groups are not solely responsible for the change in LUMO populations, what controls the LUMO? The bond angles at the acetylenic carbons given in the last columns in Table 4 can be correlated with the LUMO populations in Figure 2, where the $(f_2 - f_1)$ values are plotted against the difference in

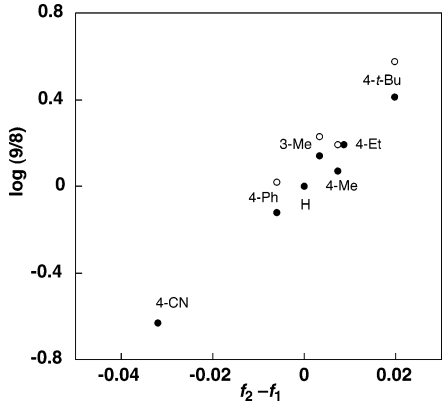


FIGURE 1. Plot of logarithms of ratios of the acetate products **9**/**8** obtained from **6** (●) and **7** (○) against the differences in LUMO populations, $f_2 - f_1$. For 3-methylcyclohexyne (3-Me), see ref 20b.

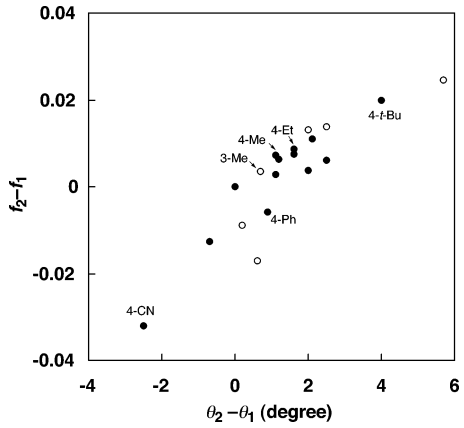


FIGURE 2. Plot of the LUMO populations ($f_2 - f_1$) versus the bond angles ($\theta_2 - \theta_1$) for 4-substituted (●) and 3-substituted (○) cyclohexynes.

the bond angles at C2 and C1, ($\theta_2 - \theta_1$). The points in Figure 2 include not only those for the optimized structures summarized in Table 4 but also those for local minimum structures. The difference in LUMO populations increases as that in bond angles increases. The acetylenic carbon of the larger bond angle (or the less deformed carbon) has a higher LUMO population and is more electrophilic than that of the smaller bond angle (or the more deformed carbon). The LUMO population is controlled by the ring structure represented by the bond angles at the acetylenic carbons. This can be further confirmed by a model calculation on the deformed cyclohexyne ring, which has the same structure of the ring of the optimized 4-*tert*-butylcyclohexyne but the *tert*-butyl group is replaced with hydrogen (the last entry of Table 4). The model calculation shows that the ring structure determines the LUMO populations but that the electronic effects of the *tert*-butyl group have a minimal influence on the LUMO.

Conclusions

Stepwise reactions of vinyl iodonium salts are subject to competition between nucleophilic and basic reactions at each step of the reaction pathways. Cyclohexyne is generated by hydro-iodonio-elimination of the cyclohexenyl iodonium salt effectively via the E2 mechanism with mild bases such as acetate and fluoride in aprotic solvents, while less efficiently via the E1 mechanism with amines. The regioselectivity of nucleophilic addition to substituted cyclohexynes is controlled by the LUMO populations, which are dependent on the ring structure. Cycloheptyne forms from cyclohexylidenemethyl iodonium salt via the E1-type mechanism involving 1,2-rearrangement in very poorly basic media. Cyclopentenyl iodonium salt could not provide cyclopentyne but undergoes the Michael addition of acetate and cyanide followed by elimination to give an allylic product.

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