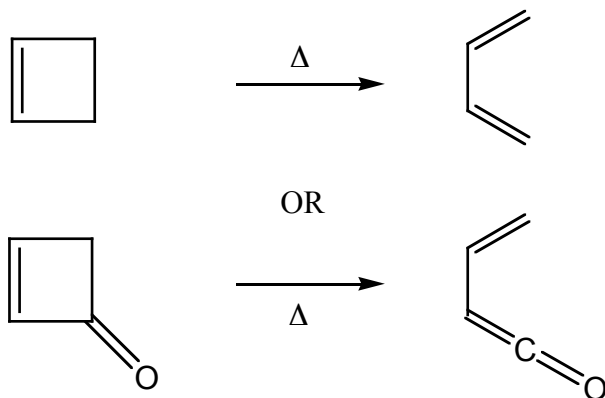


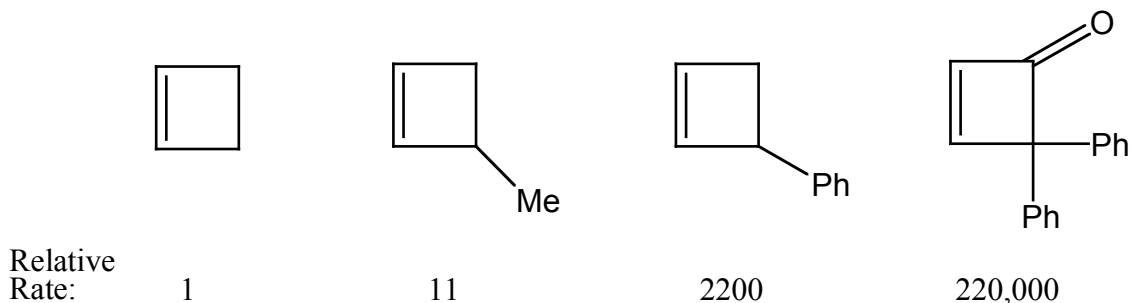
Alicyclic and Heterocyclic Chemistry. Lecture 9

Reactivity of Four-membered Rings, contd.

Electrocyclic Ring Opening of Cyclobutenes and Oxetes :The general reaction for cyclobutenes is:

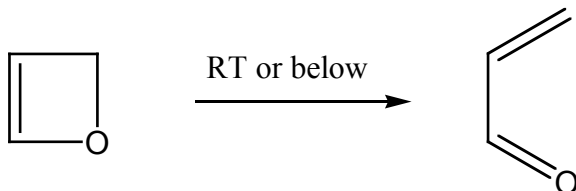


It is not always appreciated that pericyclic reactions, such as these, can be subject to substituent effects which influence the rates of reaction. The following series indicates this:



Note that increasing conjugation of the double bonds with phenyl groups in the product increases the rate of opening of the starting cyclobutene.

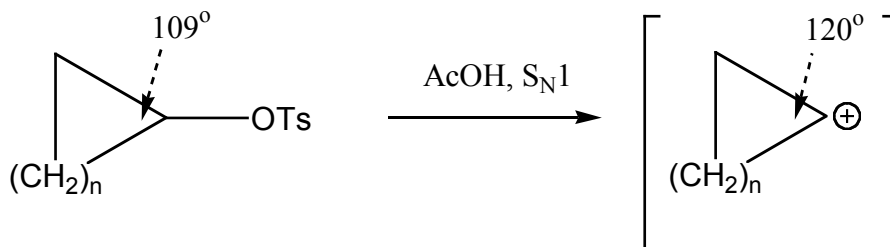
Whilst the electrocyclic ring opening of cyclobutenes generally requires heating, the analogous reaction of oxetes occurs spontaneously at room temperature:



Consequences of Reactions in which increasing Angle Strain occurs:

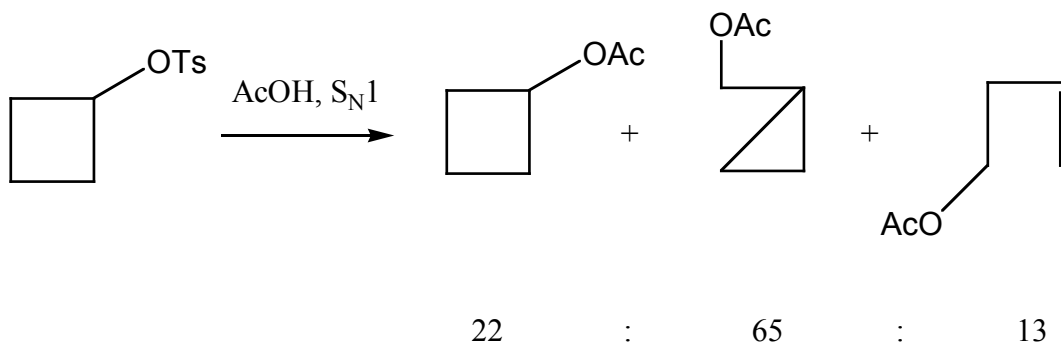
The Cyclobutyl Cation : We saw that the cyclopropyl cation was unusual with regard to both rate of formation (slow because of angle strain) and the nature of the product

(electrocyclic ring opening). Although the strain in cyclobutanes is lower than in cyclopropanes we might expect to find a similar situation when we try to form the cyclobutyl cation. Indeed, we do find that the rate of formation and the nature of the products are anomalous but not in the same way as for the cyclopropyl cation. Thus the cyclobutyl cation is formed **faster** than the cyclohexyl cation despite the increased angle strain in going from the cyclobutane precursor to the cation:

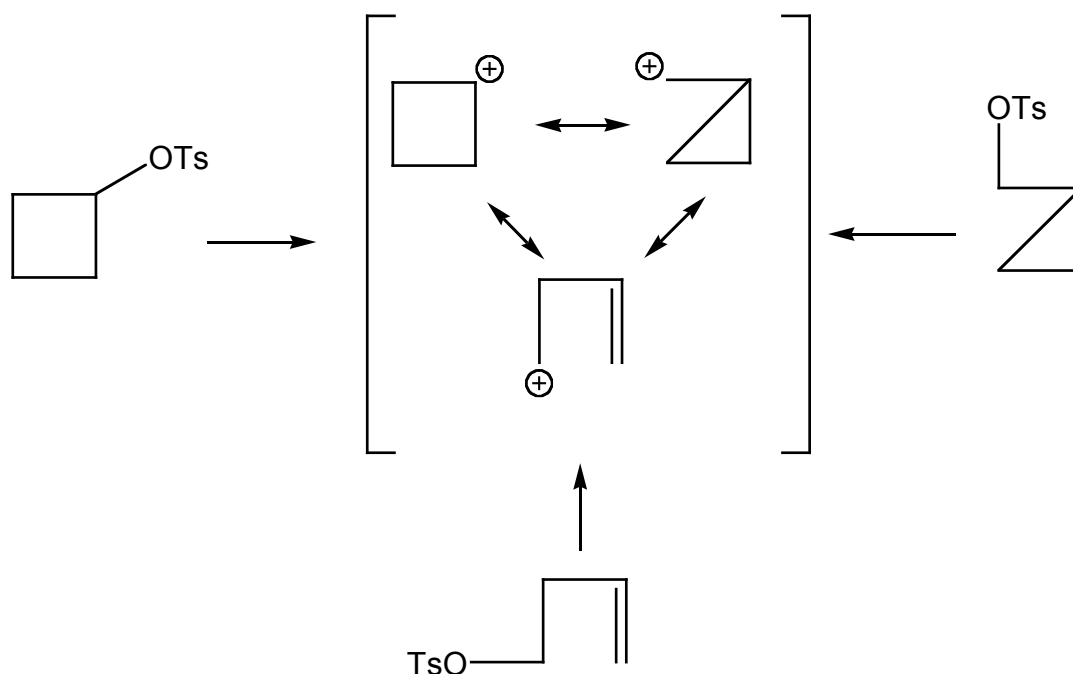


n	relative rate
4 (cyclohexyl)	1
2 (cyclobutyl)	11

Unlike the situation for the cyclopropyl cation, here the products of the reaction are not simply those of ring opening:



Indeed, the product of ring opening, the homoallyl acetate, is formed in the least amount and the most strained product, the cyclopropylmethyl acetate, is formed in the greatest!! A clue to the reason for the product distribution and the increased rate comes from the fact that both cyclopropylmethyl tosylate and homoallyl tosylate give the same products in the same ratio. Clearly we are proceeding through a common intermediate from all three starting materials and this intermediate must be resonance stabilised (hence the rate increase):



It is believed that the resonance stabilized ion resembles the cyclopropylmethyl cation most (hence the predominance of the corresponding acetate) because the orbital overlap is most effective in that shape.

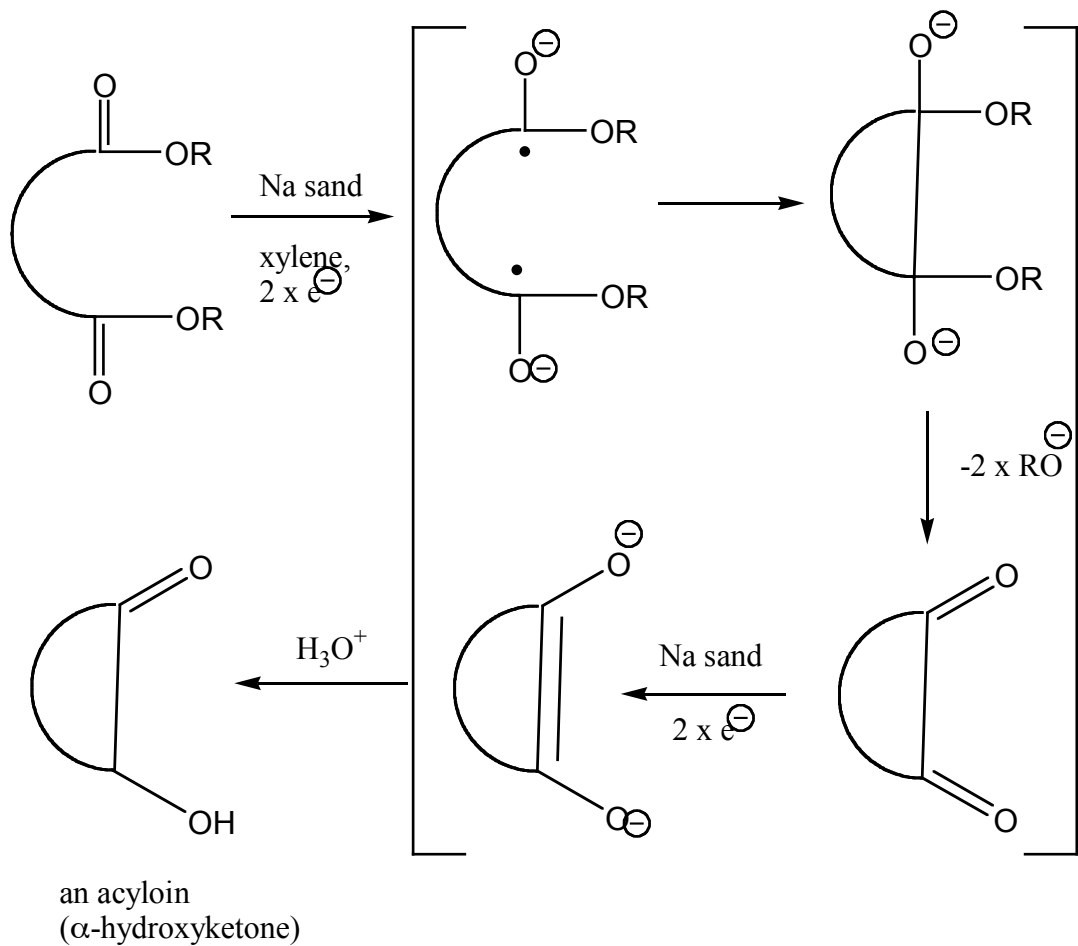
Synthesis of Medium Rings

Medium rings may be made from straight chain precursors or from smaller rings by expansion.

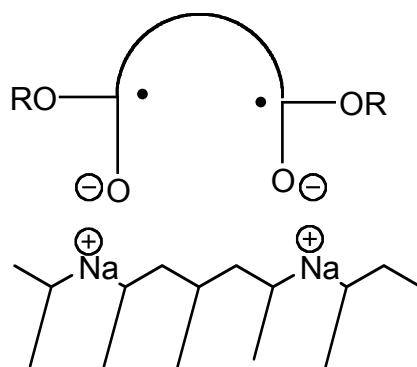
From Straight Chain Precursors : The most difficult rings to make from straight-chain precursors are medium rings, much more so than three- or four-membered rings despite the higher strain energy in the latter. The reason for this is not because of the strain energy in medium rings, which is small, but rather because of the change in entropy required to bring the distal ends of the chain together. In smaller rings the ends are not so far apart and there is little problem entropically.

The classic reaction which overcomes this entropy problem is the Acyloin Synthesis.

Acyloin Synthesis: The mechanism of the reaction is:



The reaction takes place on the surface of the sodium sand (fine particles of sand produced under the experimental conditions):



There are two advantages to this heterogeneous synthesis over those which occur in solution:

- The attraction of the oxyanions to sodium cations embedded in the surface reduces the freedom of movement of the ends of the chain thus reducing the entropy problem

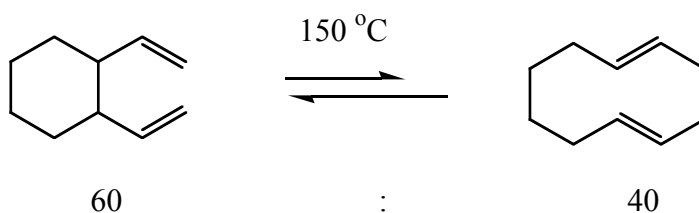
- The vast surface area of sodium sand limits the number of diradicals which come close to one another and thereby reduces the chance of polymerisation over cyclisation.

A comparison of yields from the acyloin synthesis and the solution-phase Dieckmann condensation (an intramolecular Claisen Ester condensation) indicates the advantage of a surface reaction:

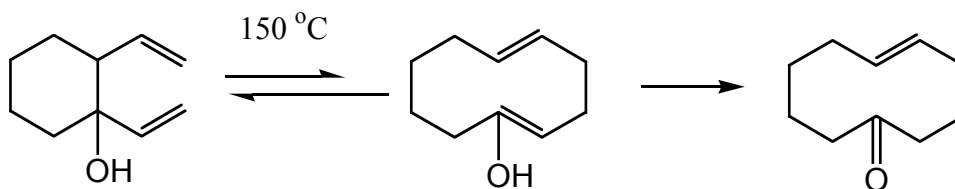
<u>Size of Ring</u>	<u>Dieckmann Yield</u>	<u>Acyloin Yield</u>
7	47	52
8	14	36
9	6	38
10	0	65
11	0	66
12	0	80

By Ring Expansion :

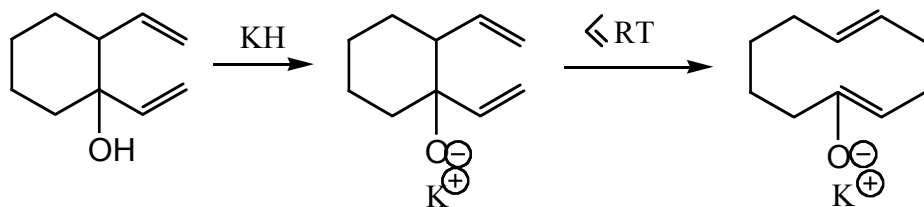
Cope Rearrangement of Divinyl-cyclohexanes: The Cope rearrangement ([3,3]-sigmatropic shift) of divinyl cyclohexanes is an equilibrium reaction which lies on the side of the cyclohexane because of the strain in the medium ring:



This can be overcome by using the Oxy-Cope rearrangement in which the first formed product is removed from the equilibrium by ketonisation:



This still requires heating but the alkoxide analogue, known as the Oxyanion Cope rearrangement, proceeds at room temperature or below, provided the counter-cation is potassium:



The failure of the reaction using other Group 1 cations is not well understood.

The geometry of the double bonds in the product cyclodecadiene is dependent upon the stereochemistry of the starting divinyl-cyclohexane since the reaction proceeds through a chair transition state:

