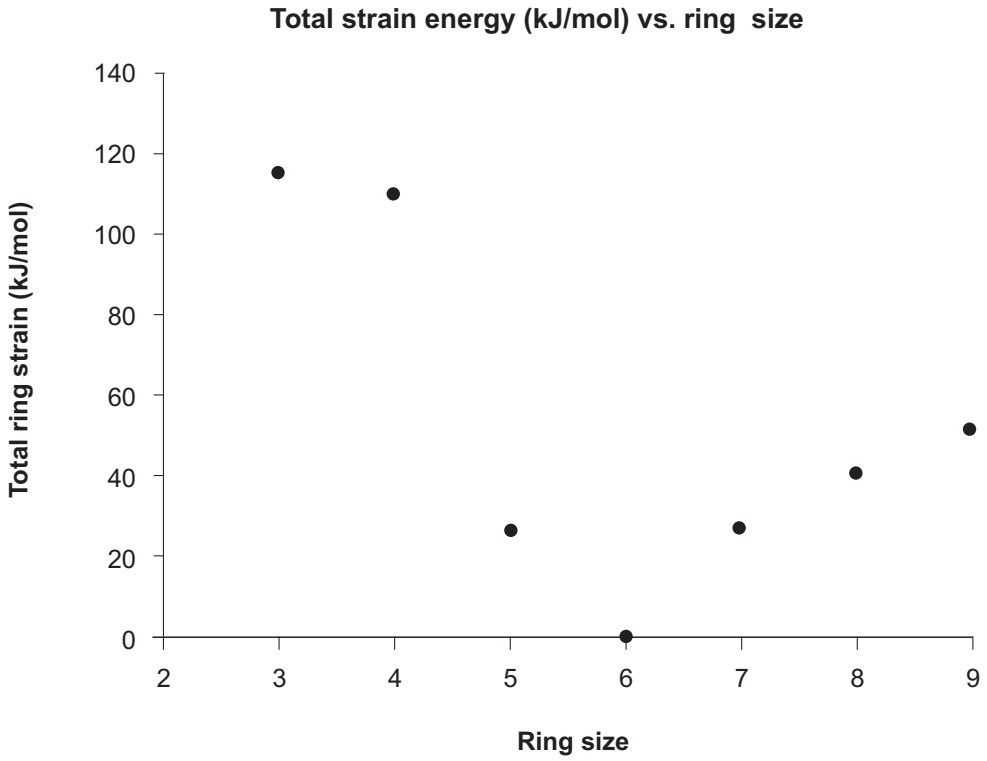
Activity 13 Ring Closures

Focus Question

What factors affect polar ring closure reactions?

Model 1

Review of Ring Strain

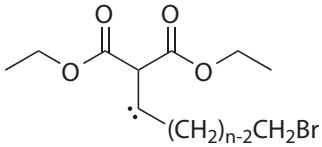


1. What cycloalkane (e.g. cyclopropane, cyclobutane, cyclopentane, etc.) has the lowest ring strain?

2. What cycloalkane has the highest ring strain?

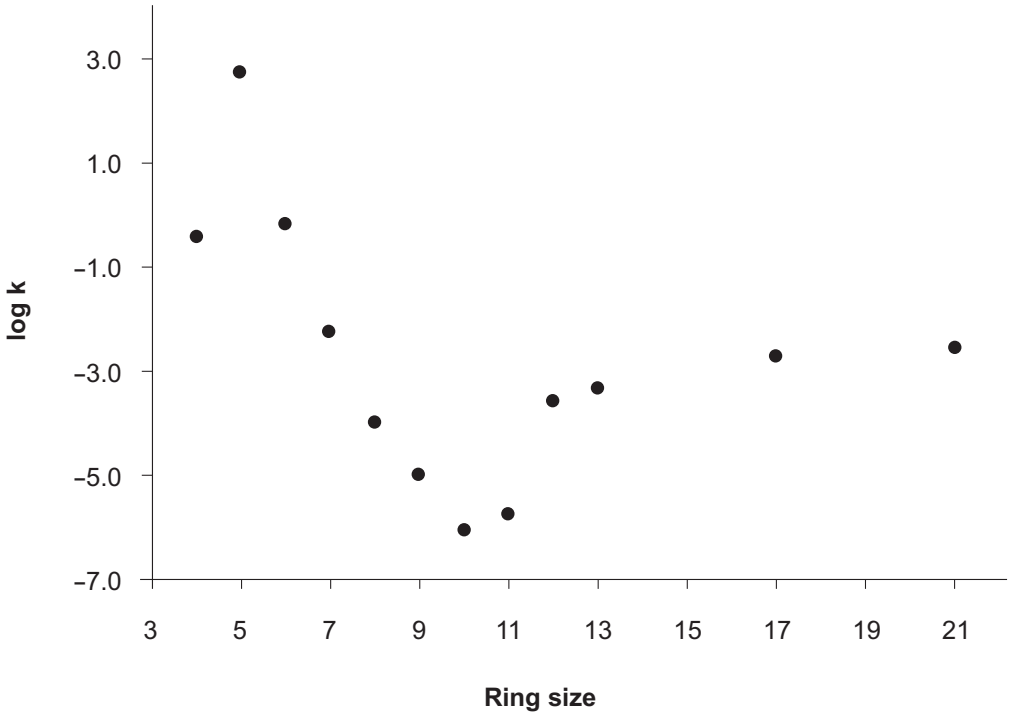
Model 2

Ring Closure of diethyl (ω-bromoalkyl) malonates



Diethyl (ω-bromoalkyl) malonates

log k versus the final ring size for ring closures of diethyl (ω-bromoalkyl) malonates



3. Draw the mechanism and product of the ring closure of the diethyl (ω-bromoalkyl) malonate in which n = 5.

4. What does n stand for?

5. Why does the $(CH_2)_{n-2}$ group have the subscript n-2 rather than n?

6. What is k?

7. For what ring size is this reaction the fastest?

8. For what ring size is this reaction the slowest?

9. Compare the graph in Model 1 to that in Model 2. Does the strain of the ring being formed account for the rate at which this reaction occurs? Explain your reasoning.

Review

Gibb's Free Energy

10. What is the equation for Gibb's free energy?

11. What does H stand for? What does S stand for?

12. Under what term does ring strain fall, H or S?

Information

Entropy

In addition to ring strain, the rate of alkane ring closure also depends on the change in entropy during the reaction.

13. The number of degrees of freedom in a system is the number of variables that can change. In terms of alkanes and cycloalkanes, the degree of freedom is proportional to the number of different conformations a molecule can adopt. Which has more degrees of freedom:

    circle one: *an n-alkane* *the corresponding cycloalkane*

14. ΔS is the change in entropy, or randomness, of a system. If ΔS is positive, the randomness of the system has:

    circle one: *increased* *decreased*

15. What sign do you expect ΔS to have for ring closure?

16. Consider n-alkanes where n = 3 − 9. For what n do you expect ring closure to be entropically most favorable? Least favorable?

17. Explain why the graph in Model 2 has a different shape than the graph in Model 1. For example, why is the ring closure of diethyl (ω-bromobutyl) malonate relatively slow even though the five-membered ring produced has only a small amount of ring strain?

Review

18. In a reaction between a nucleophile and an electrophile, the _____ (HOMO or LUMO) of the electrophile reacts with the _____ (HOMO or LUMO) of the nucleophile?

19. The HOMO and the LUMO of ethylene are drawn for you. Cross out the orbital that will **not** react with a nucleophile.

20. Using an arrow, indicate on ethylene's LUMO from what direction a nucleophile is most likely to attack. There may be more than one spot, but just pick one. Hint: Think orbital overlap.

Information

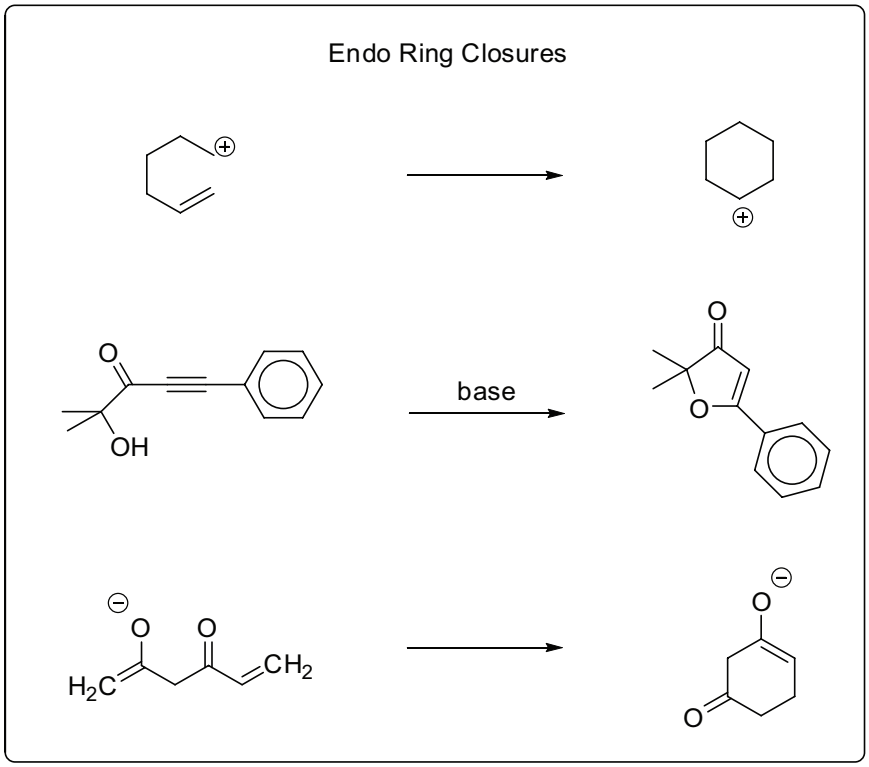
Using experimental data, Dunitz and Bürgi found that nucleophilic attack at a carbonyl carbon occurs at 105°. The same angle of attack is seen in nucleophilic additions to alkenes and alkynes. This angle is known as the Bürgi-Dunitz angle.

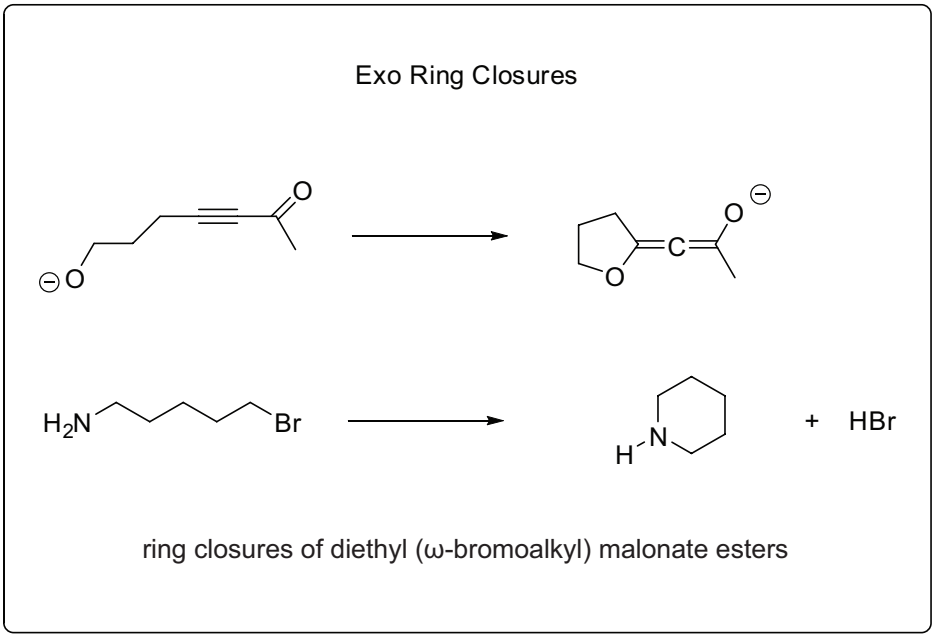
21. Based on molecular orbitals, list two reasons that the Bürgi-Dunitz angle is not 90°. Hint: One reason involves the HOMO of the electrophile and one the LUMO of the electrophile.

MODEL 4

Endo and Exo Ring Closures

In addition to entropy and enthalpy, stereoelectronic factors also affect the rate of ring closures. One such factor is the type of ring closure, endo or exo.





ring closures of diethyl (ω-bromoalkyl) malonate esters

22. Draw the mechanism for each endo ring closure in Model 4.

23. Draw the mechanism for each exo ring closure in Model 4.

24. What is the difference between endo and exo closures?

25. Define an exo ring closure.

26. Define an endo ring closure.

Model 5

Baldwin's Rules

Professor Jack Baldwin noticed trends in favorability of ring closures based on ring size, stereochemistry of attack (endo or exo) and hybridization of the atom undergoing attack. These trends help us to predict the most likely ring formed in a polar ring closure reaction, and they are commonly known as Baldwin's rules.

	Exo			Endo	
Ring size	**dig (sp)**	**trig (sp^2)**	**tet (sp^3)**	**dig (sp)**	**trig (sp^2)**
3	unfavorable	favorable	favorable	favorable	unfavorable
4	unfavorable	favorable	favorable	favorable	unfavorable
5	favorable	favorable	favorable	favorable	unfavorable
6	favorable	favorable	favorable	favorable	favorable
7	favorable	favorable	favorable	favorable	favorable

27. To what atom in a ring closure reaction do the dig, trig, and tet labels refer?

28. The ring closure reaction with diethyl (ω-bromoalkyl) malonate in which n = 5 is labeled 5-exo-tet in terms of Baldwin's rules. Label each of the reactions in Model 4 appropriately.

29. Label each reaction in Model 4 as favorable or unfavorable according to the chart above.

30. Individually, draw out an example of a 4-exo-dig ring closure.

31. Have your group check your answer to question 30. Remember that there are many correct answers, so answers can differ among group members.

32. Individually draw out an example of a 5-endo-trig ring closure.

33. Have your group check your answer to question 32. Remember that there are many correct answers, so answers can differ among group members.

34. According to Baldwin's rules, what are the two types of hybridization for which ring closure can be unfavorable?

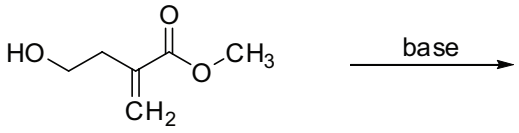
35. Using the reaction you drew for question 32, explain why this reaction is unfavorable. Your explanation must involve molecular orbitals.

36. For the following reaction,

a. draw the intermediate that forms from the starting material reacting with base;

b. draw out the products from the two possible ring closures (assuming work-up with dilute acid);

c. circle the product that will be favored.



Revisiting the Focus Question

What factors affect polar ring closure reactions?