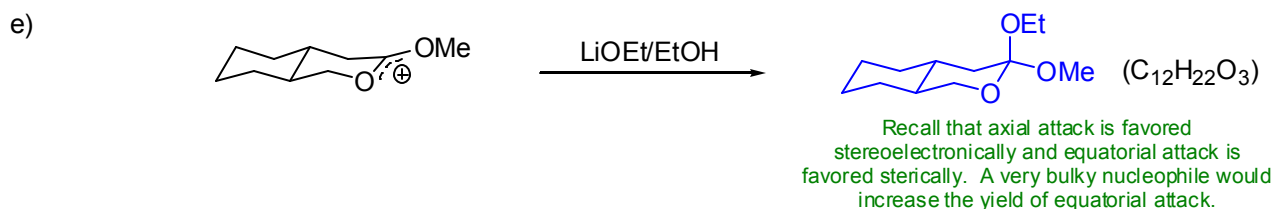
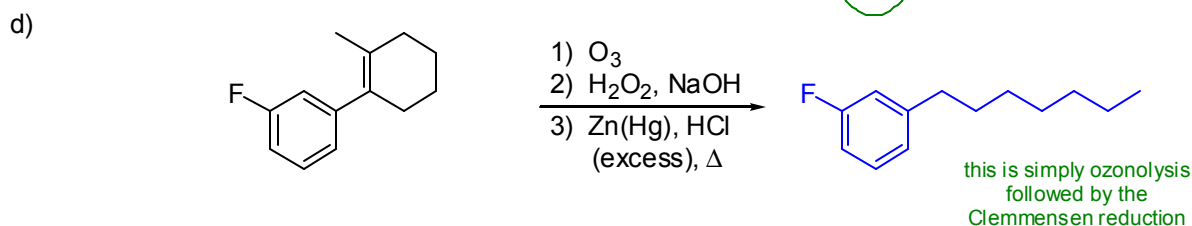
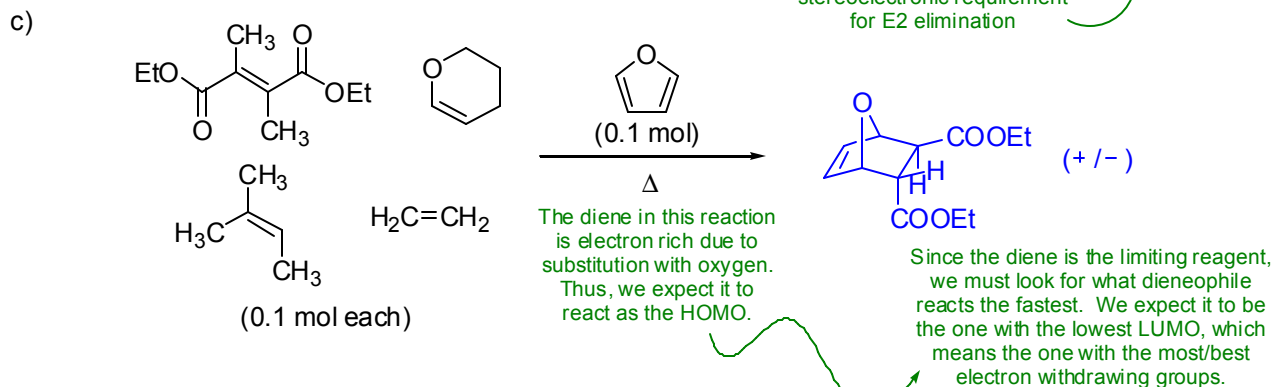
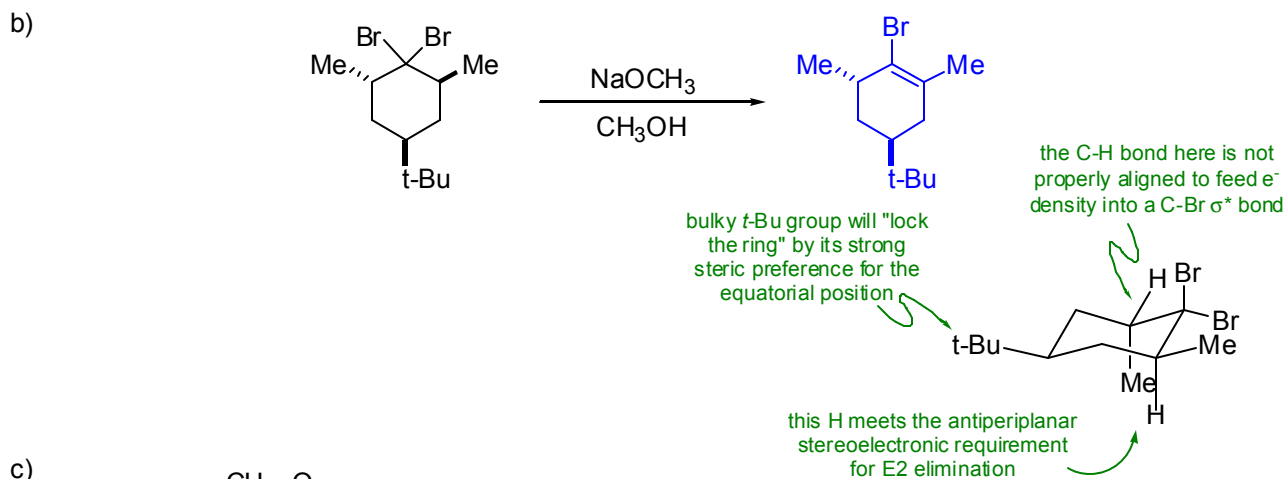
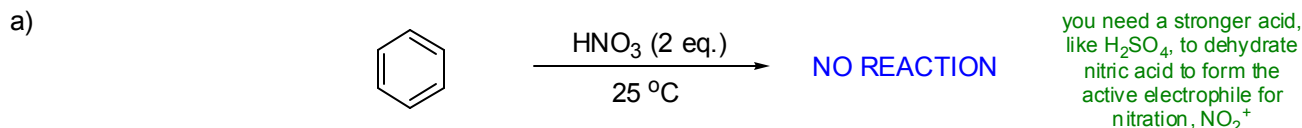


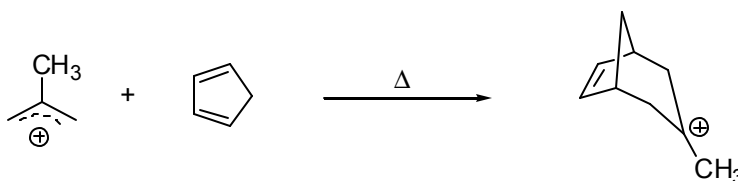
Section Solution Set

Bonding, MO Theory, Aromatic Substitution, and More

Problem 1 (parts a-d original, part e based on Kirby's *Stereoelectronic Effects*). Predict the major product for each of the following reactions. Beware of trick questions designed to embarrass you and break your spirit.



Problem 2 (based on material in *Frontier Orbitals and Organic Chemical Reactions* by I. Fleming). Taste the rainbow of fruit flavor in the following cycloaddition reaction:

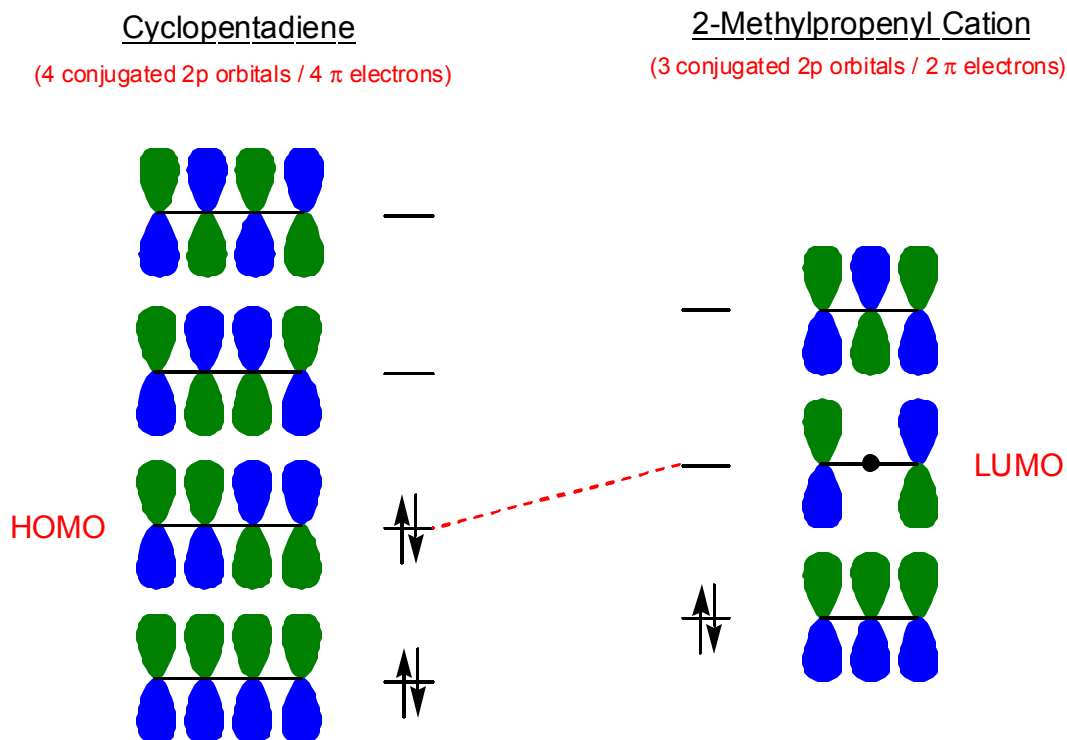


Solution

a) Classify the reaction as [m+n]

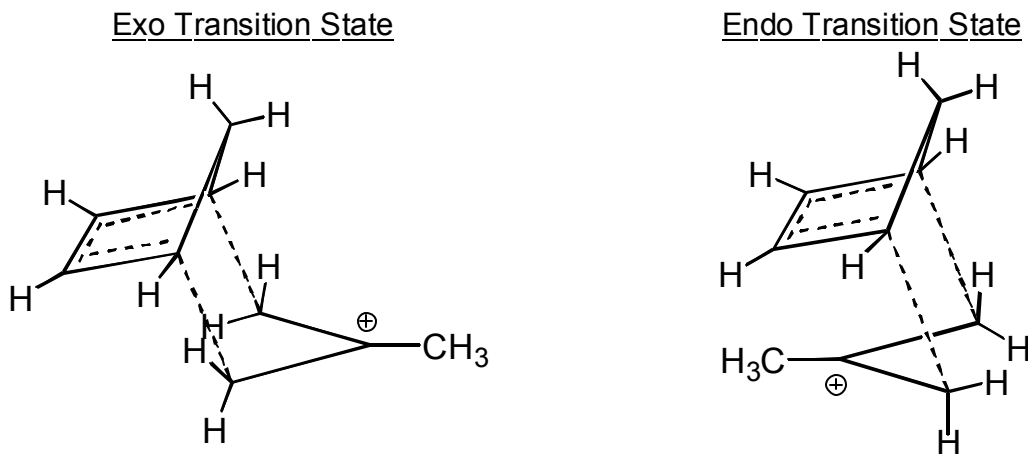
This is a [4+3] cycloaddition.

b) By combining unhybridized p atomic orbitals on each molecule, build all of the π molecular orbitals for both reactants. Label the HOMO and the LUMO in this reaction and explain why the reaction is expected to be concerted under thermal conditions.

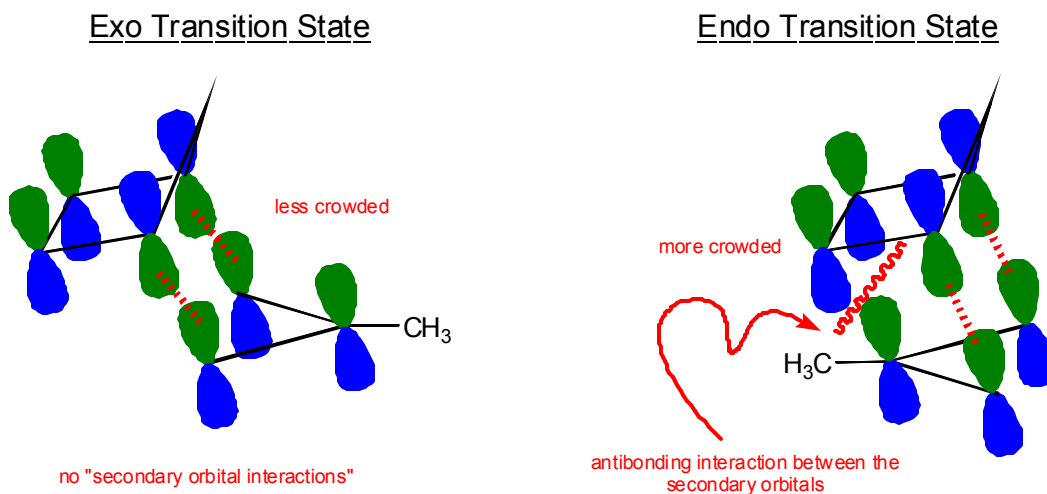


We expect the allyl cation to serve as the electrophile (provide the LUMO) because it is positively charged. The cyclopentadiene makes a good nucleophile for this cycloaddition as it bears electron donating substituents, raising the HOMO.

- c) Although there are no consequences in the stereochemistry of the product shown above, there is experimental evidence that the reaction proceeds through an exo transition state. Using dotted lines to represent bonds that are being made and broken, draw a Lewis structure for the exo transition state that shows me that you know the difference between “endo” and “exo” cycloaddition transition states.



- d) Recall that Diels-Alder reactions usually prefer endo transition states (due to favorable secondary orbital overlap). Using MO theory, suggest a reason that the exo transition state is favored. **HINT: Regardless of your assignment in part b, use the HOMO of the cation and the LUMO of cyclopentadiene.**



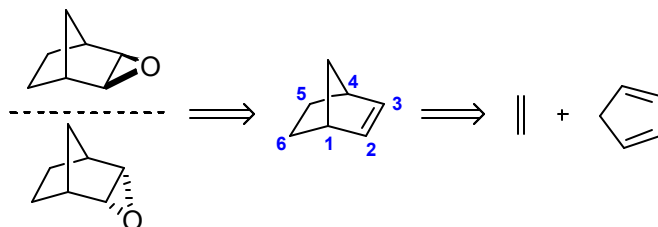
The Diels-Alder addition typically proceeds through an endo transition state. Although the endo transition state is typically more crowded, we attribute its predominance to favorable secondary orbital interactions. In the present case, when you superimpose the p orbitals of the HOMO and LUMO on to the transition state structure (be sure to keep track of the wavesigns), you find that the secondary orbital interaction is antibonding (see above). This unfavorable interaction may explain this particular reaction's preference for the exo transition state.

Problem 3 (a common example—I might have seen it somewhere in Evans' lecture slides, too. I try not to plagiarize problems). If you want to be able to set up your own home meth lab, you'll have to master organic synthesis. Starting from any molecules bearing five carbons or fewer, provide concise synthetic routes to the following two compounds.

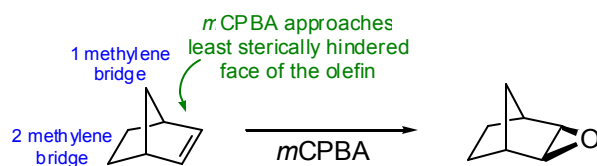


Solution

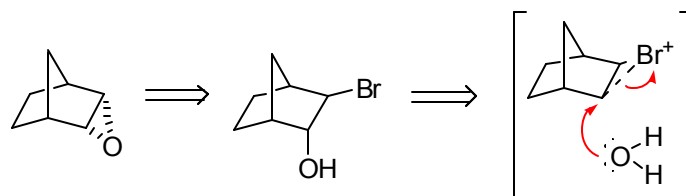
- Here is a good place to distinguish between “real life” and Chem 30. In real life, you can buy these or the norbornene precursor. In Chem 30, we make you run through some lame reactions to show us you know them. If you go to chemistry grad school, your boss will never tell you only to use starting materials with five or fewer carbons. If something is available commercially, we generally don't waste time making it.
- Just taking a look at the products, the only functionality remaining in the compounds are epoxides. The preferred method we've learned for making these compounds is the treatment of an olefin with a percarboxylic acid, such as mCPBA. Thus, let's work backwards from the products to an olefin as a starting point:



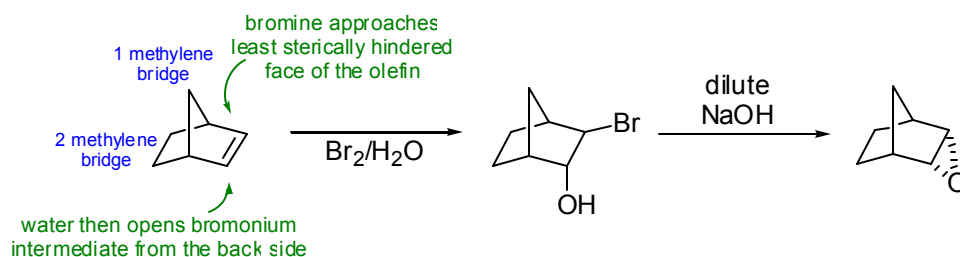
- Note that the olefin has a six membered ring, which I've numbered. Anytime you see a six membered ring, you should think Diels-Alder. A Diels-Alder won't always work, but it's something to try. Whenever you see a cyclohexene in a synthetic intermediate, this should *scream* Diels-Alder at you. Continuing to work backwards, as one usually does in synthetic problems, the Diels-Alder reactants are shown. They meet the five-carbons-or-fewer criterion given to us in the prompt. Always remember to RTFP (Read The... Problem) so you don't lose points breaking the rules.
- Let's go back to the epoxidation. By a steric analysis, we expect this to yield the diastereomer shown below.



- So how do we make the other isomer? Another way we know to make ethers is by the substitution of alkyl halides with alcohols. If we work backwards, we can draw the precursor to the final product.

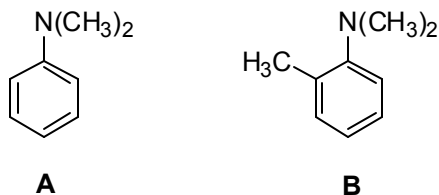


- The intermediate, a bromohydrin, should seem familiar from Chem 20. We make them by treating alkenes with aqueous bromine. The bromonium forms with the bromine on the less hindered face of the olefin. When water opens this intermediate from the back side, the oxygen adds to the more hindered face of the olefin. Treatment with base effects intramolecular S_N2 displacement to yield the “other” epoxide product:



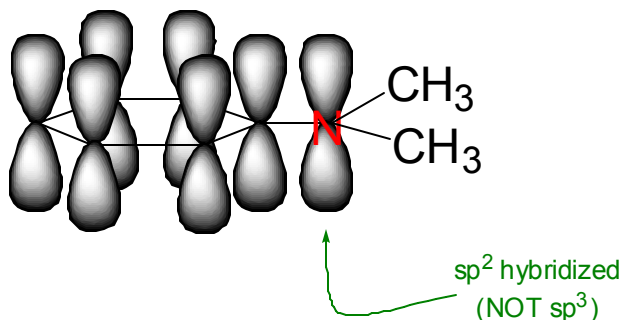
- In the end, you should know how to do these at first glance. Do practice syntheses until these cute little problems become instinctive—you don't have any time to waste on an hour exam.

Problem 4 (a common example). Even though compound **B** has an extra electron donating substituent on its ring, compound **A** reacts significantly faster in electrophilic aromatic substitution reactions. Explain this ostensibly counterintuitive observation.

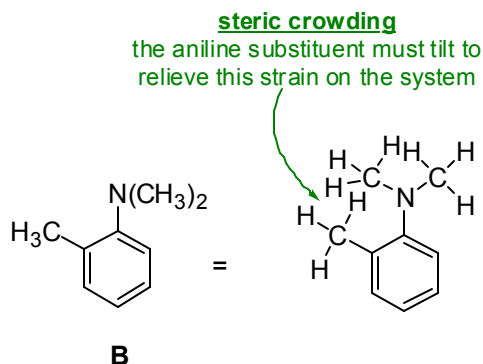


Solution

Recall that amino substituents activate the ring because the filled nonbonding orbital on nitrogen overlaps with the aromatic π system, increasing electron density in the ring and thus increasing its nucleophilicity. By this resonance effect, the nitrogen substituent can also stabilize positive charges that develop in the transition state. It is important to realize that heteroatoms (e.g. N, O) typically adopt an sp^2 hybridization if they are next to a π system. The energetic cost of assuming this geometry is compensated for by stronger orbital overlap. Thus, we would expect N,N-dimethylaniline (**A**) to look like:



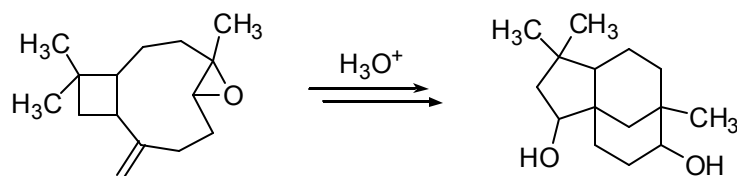
So the question becomes: how does that methyl group screw up this effect? Perhaps it is easier to see by drawing out the complete Lewis structure:



The electron clouds of the ortho methyl substituent and one of the methyl groups on the nitrogen will repel. This causes the molecule to tilt out of planarity, resulting in worse overlap between the filled p orbital on the nitrogen and the aromatic ring. In this geometry, the activating electronic effect described above is attenuated—resonance effects diminish as orbital overlap decreases.

Update: A similar problem showed up in lecture on Wednesday, October 6th. By now you should have a general sense of what the man likes.

Problem 5 (based on material from *Advanced Organic Chemistry* by B. Miller, p. 148). Provide an arrow pushing mechanism for the following transformation. No, this is not busy work.



Solution

See the section 2 handout for common steps in these types of carbocation rearrangement problems. If you work a number of these problems, you'll notice some common themes (formation of five/six membered rings, shifts to more stable cations, loss of water to make double bonds, etc.) Usually these reactions are catalyzed with acid (proton or a metallic Lewis acid), which is used to "activate" part of the compound by rendering it electrophilic. Sometimes you see carbocations generated by loss of a good leaving group. Whatever the case, be sure to practice good atom/electron bookkeeping so you avoid careless errors—number carbons if it helps you.

