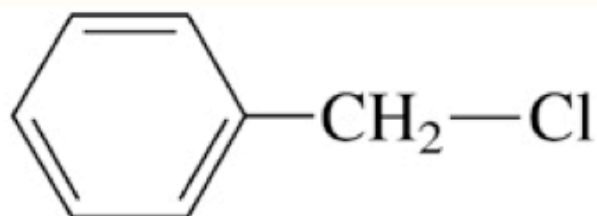


S_N2 Reactions of Benzylic Halides

S_N2 of benzylic halides is faster than allylic halides.

How can this be explained if there is no carbocation intermediate?



Benzyl chloride

Most reactive: $k(\text{rel})$ 197



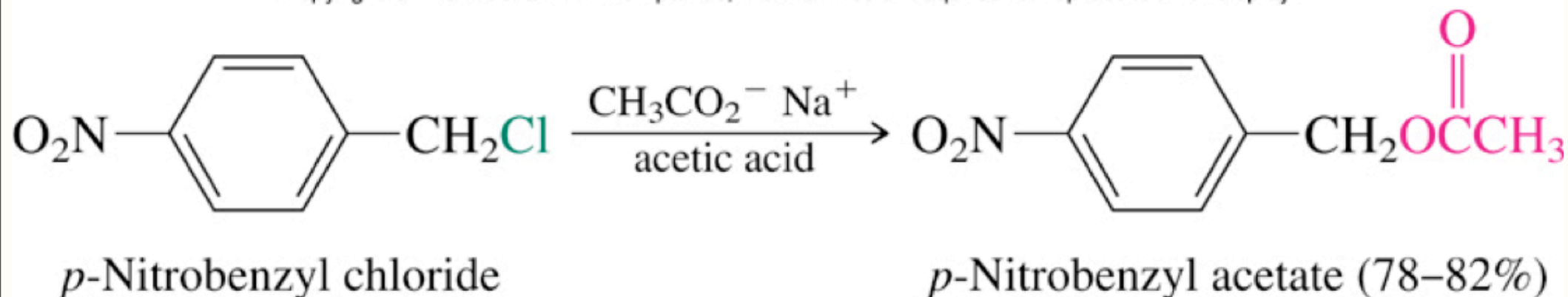
Allyl chloride

$k(\text{rel})$ 80



1-Chloropropane

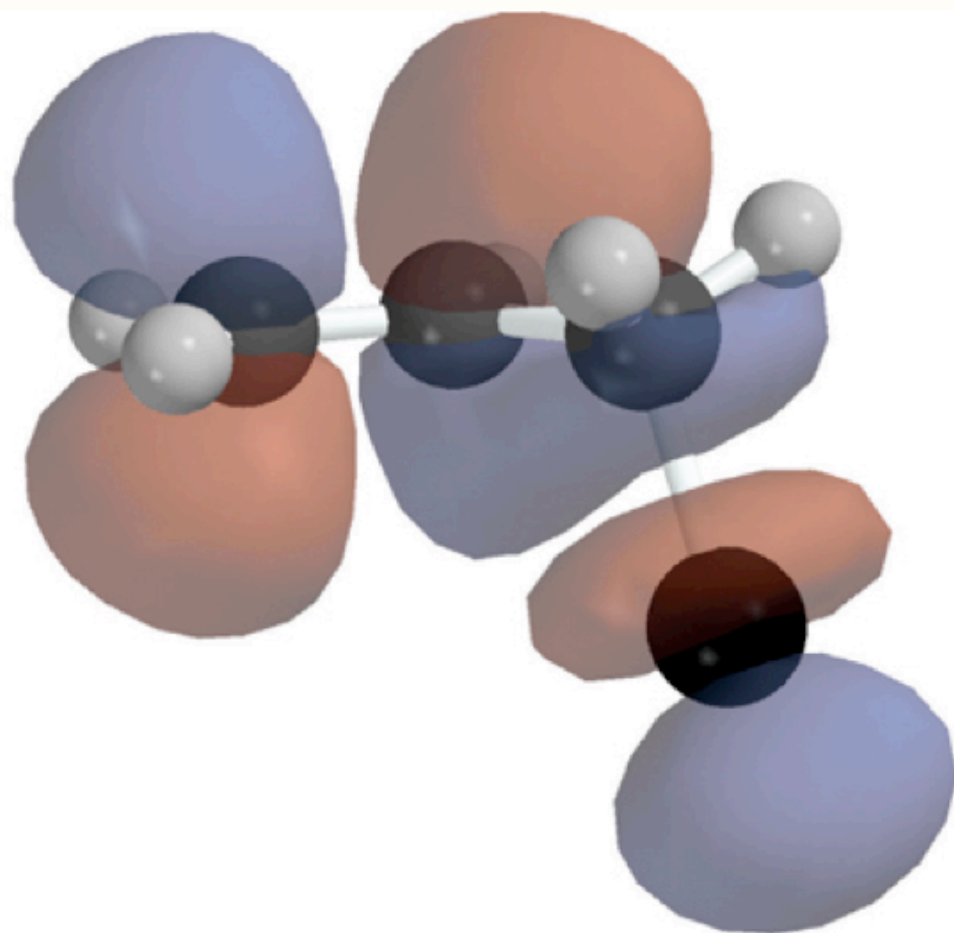
Least reactive: $k(\text{rel})$ 1.0



Allylic SN2 Faster: Two Arguments

1. steric hinderance (VWF)

2. molecular orbital interactions

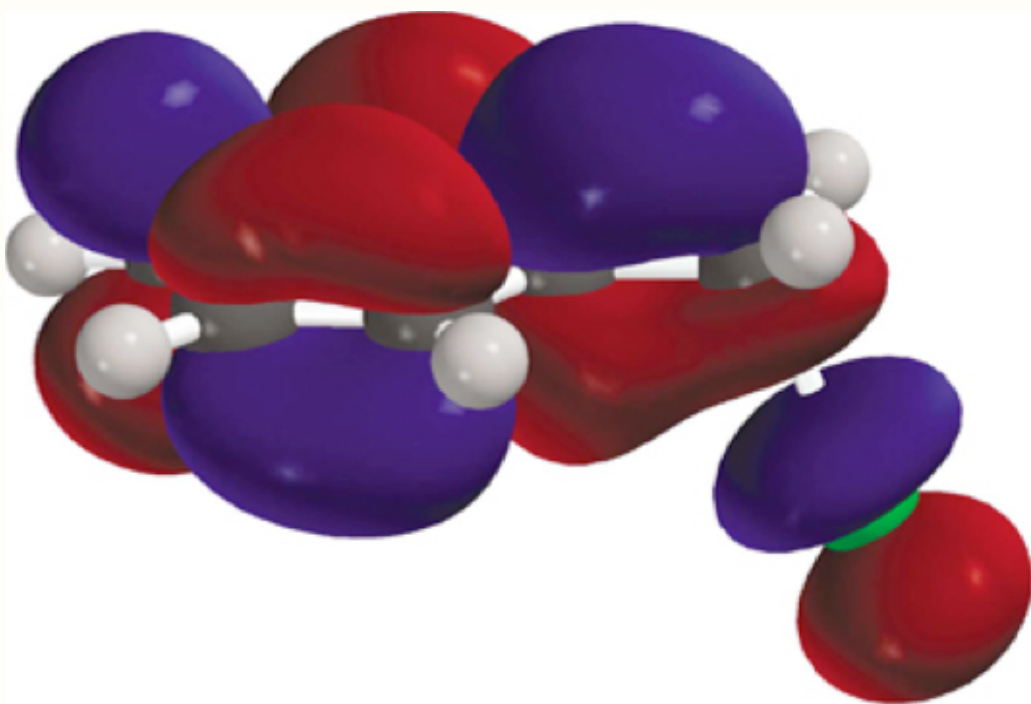
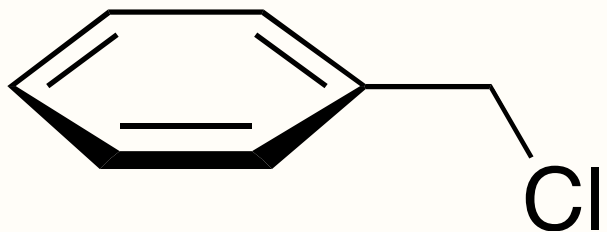


- LUMO of C-X bond can adopt a coplanar arrangement with p-orbitals of p-bond =
- electron delocalization over three orbitals =
- lower energy LUMO =
- lower activation energy =
- faster reaction
- *Why does lower energy LUMO result in lower activation energy?*

Benzylic S_N2 Faster: Two Arguments

1. steric hinderance (VWF)

2. molecular orbital interactions

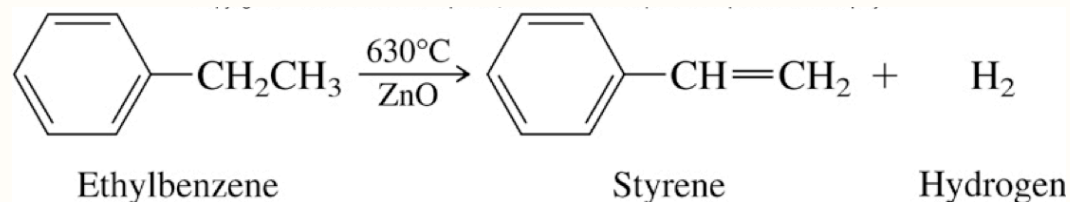


- LUMO of C-X bond can adopt a coplanar arrangement with p-orbitals of p-bond =
- more p-orbitals in benzene than alkene =
- more electron donation into LUMO of C-Cl bond =
- weaker C-X bond =
- *faster reaction*

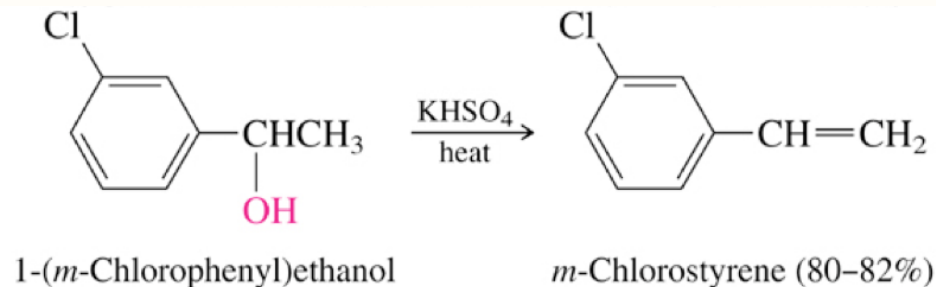
Preparation of Alkenylbenzenes

Same methods used to prepare alkenes can be used to prepare alkenylbenzenes

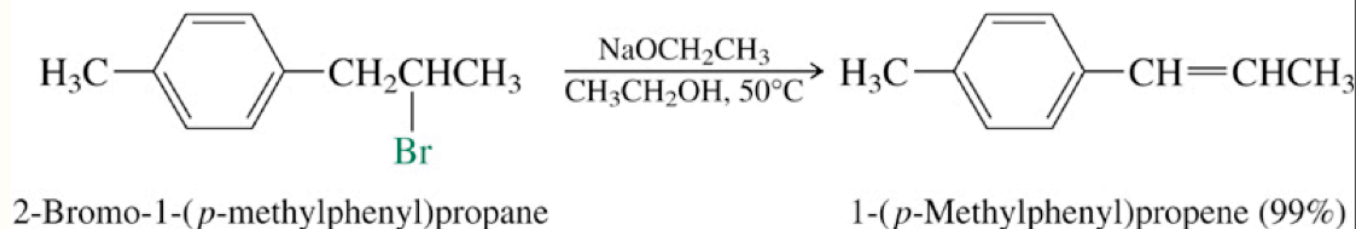
Dehydrogenation



Dehydration



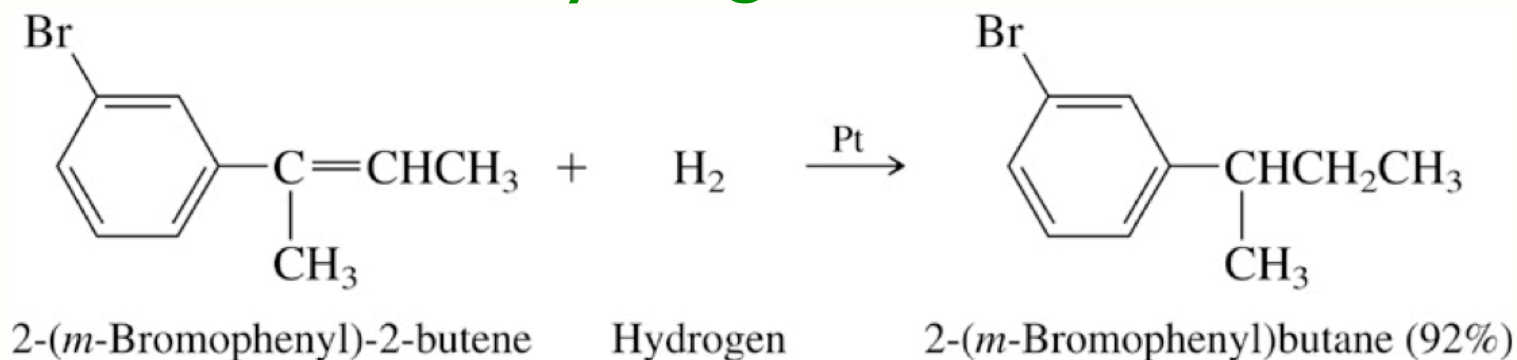
Dehydrohalogenation



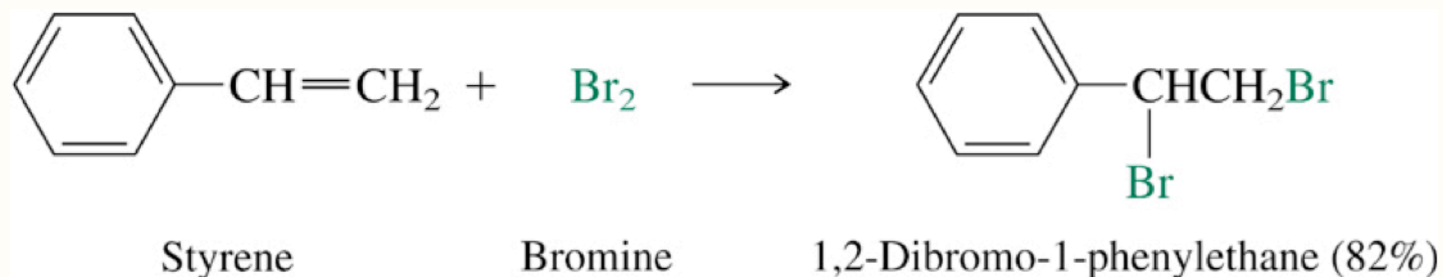
Elimination of Benzylic Hydrogens

Addition reactions to alkenes can also be applied to addition reactions to alkenylbenzenes

Hydrogenation

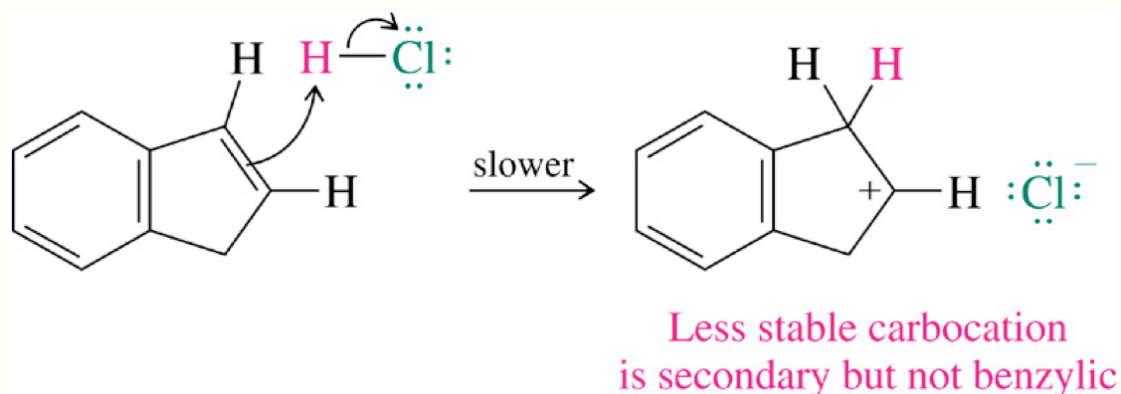
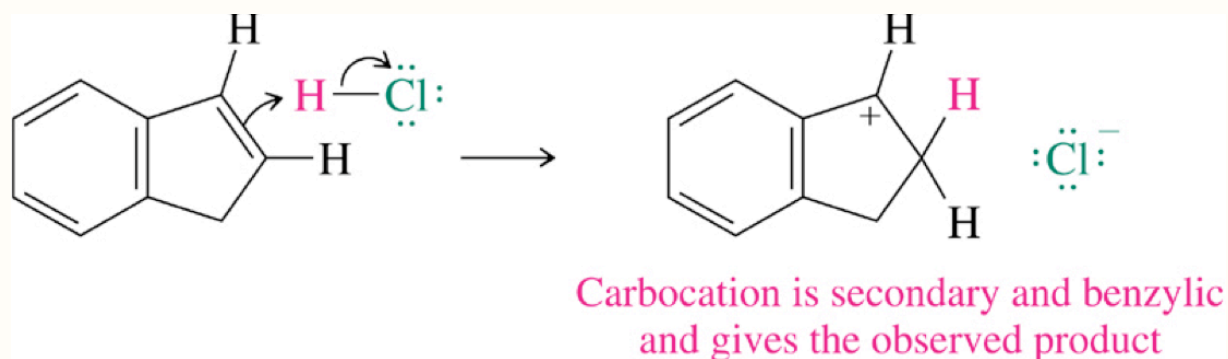


Bromination



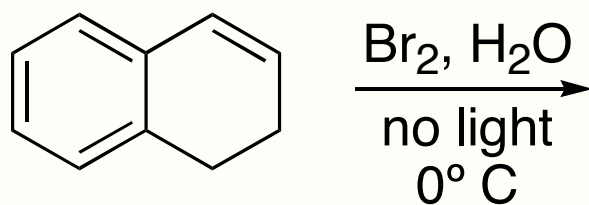
Regioselective Addition of Electrophiles to Alkenylbenzenes

Addition to alkenylbenzenes favors (faster) formation of the more stable benzylic carbocation



Self Test Question

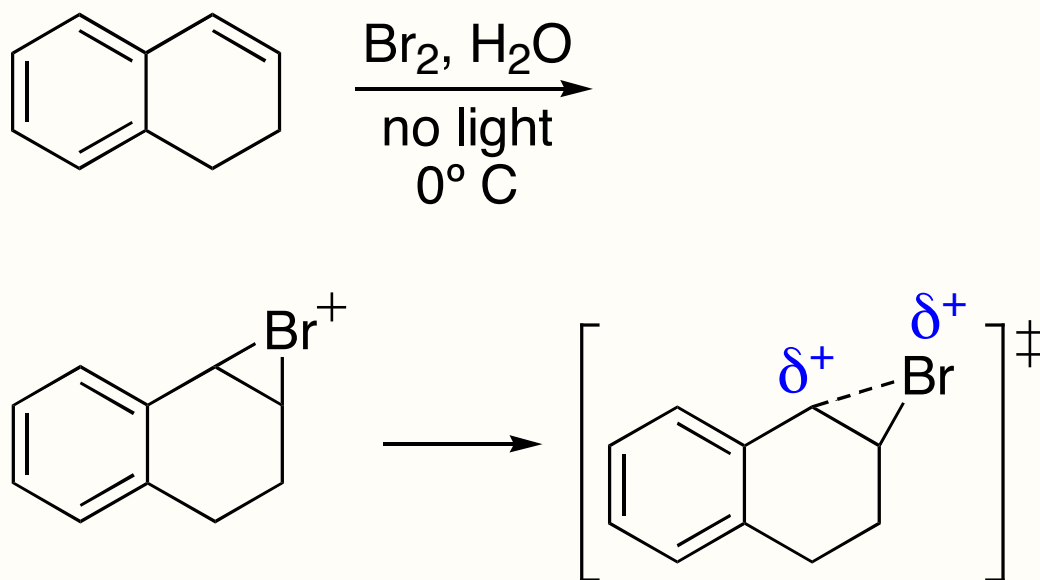
What is the *major regioisomeric* halohydrin formed by the reaction below?



- A
- B
- C
- D
- E

Self Test Question

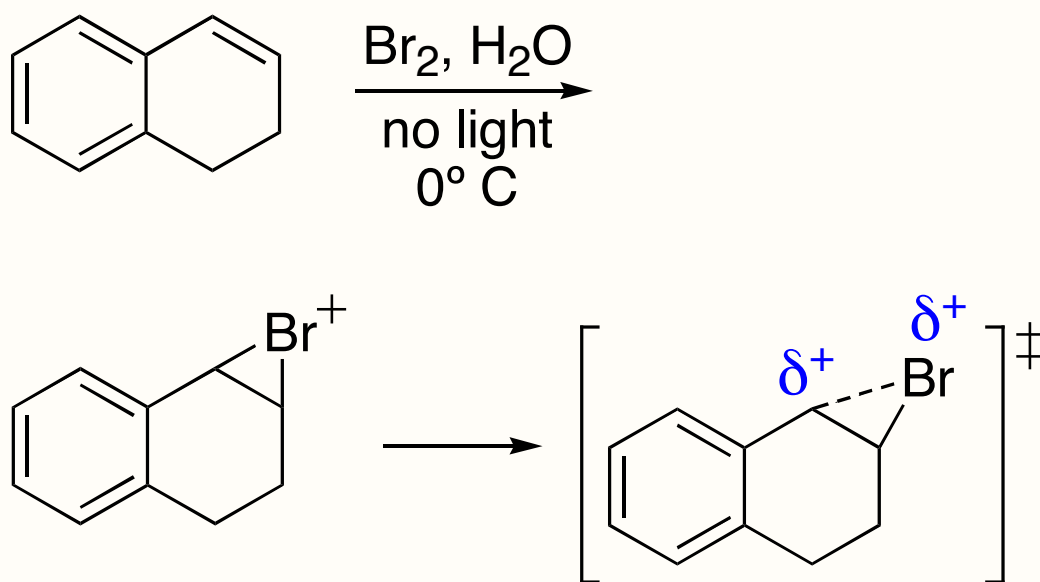
What is the *major regioisomeric* halohydrin formed by the reaction below?



- A
- B
- C
- D
- E

Self Test Question

What is the *major regioisomeric* halohydrin formed by the reaction below?



- A
- B
- C
- D**
- E

Lecture 26

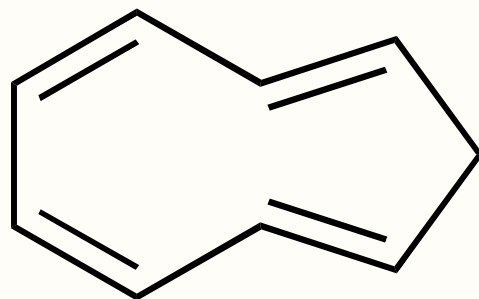
Organic Chemistry 1

Professor Duncan Wardrop

April 15, 2010

Self Test Question

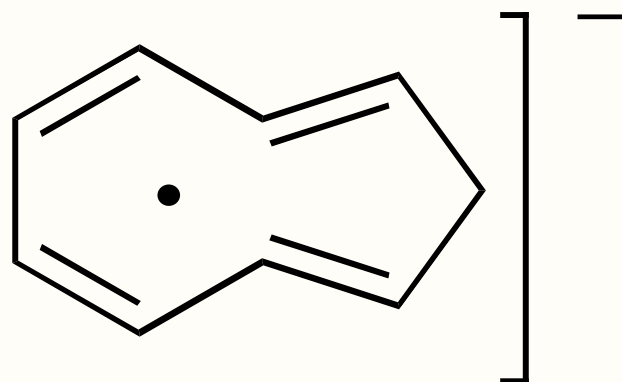
With respect to cyclononatetraene, which process below will form an aromatic species?



- A. addition of one π -electron to give $C_9H_{10}^-$
- B. addition of two π -electrons to give $C_9H_{10}^{2-}$
- C. loss of H^+ from the sp^3 -hybridized carbon to give $C_9H_9^-$
- D. loss of H^+ from an sp^2 -hybridized carbon to give $C_9H_9^-$
- E. loss of $:H^-$ from the sp^3 -hybridized carbon to give $C_9H_9^+$

Self Test Question

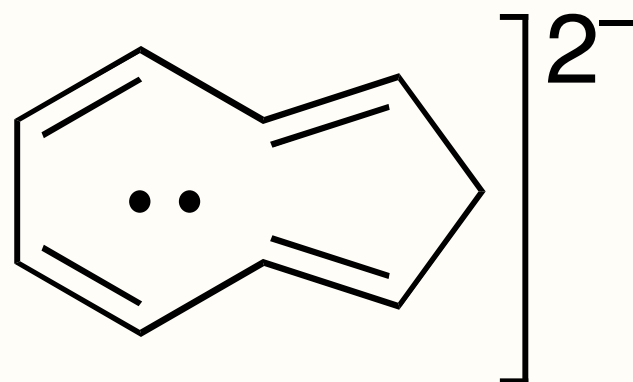
With respect to cyclononatetraene, which process below will form an aromatic species?



- A. addition of one π -electron to give $C_9H_{10}^-$
- B. addition of two π -electrons to give $C_9H_{10}^{2-}$
- C. loss of H^+ from the sp^3 -hybridized carbon to give $C_9H_9^-$
- D. loss of H^+ from an sp^2 -hybridized carbon to give $C_9H_9^-$
- E. loss of $:H^-$ from the sp^3 -hybridized carbon to give $C_9H_9^+$

Self Test Question

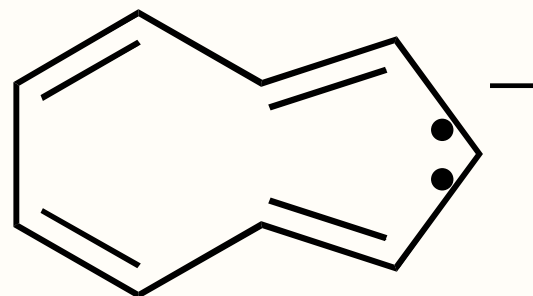
With respect to cyclononatetraene, which process below will form an aromatic species?



- A. addition of one π -electron to give $C_9H_{10}^-$
- B. addition of two π -electrons to give $C_9H_{10}^{2-}$**
- C. loss of H^+ from the sp^3 -hybridized carbon to give $C_9H_9^-$
- D. loss of H^+ from an sp^2 -hybridized carbon to give $C_9H_9^-$
- E. loss of $:H^-$ from the sp^3 -hybridized carbon to give $C_9H_9^+$

Self Test Question

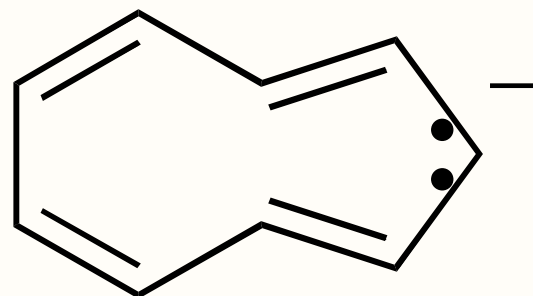
With respect to cyclononatetraene, which process below will form an aromatic species?



- A. addition of one π -electron to give $C_9H_{10}^-$
- B. addition of two π -electrons to give $C_9H_{10}^{2-}$
- C. loss of H^+ from the sp^3 -hybridized carbon to give $C_9H_9^-$
- D. loss of H^+ from an sp^2 -hybridized carbon to give $C_9H_9^-$
- E. loss of $:H^-$ from the sp^3 -hybridized carbon to give $C_9H_9^+$

Self Test Question

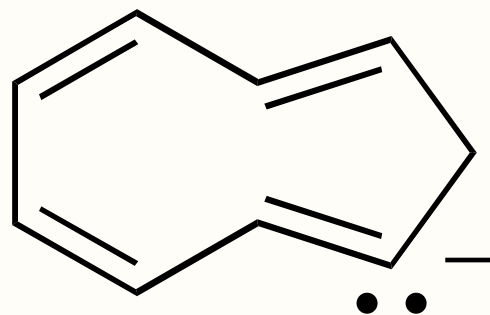
With respect to cyclononatetraene, which process below will form an aromatic species?



- A. addition of one π -electron to give $C_9H_{10}^-$
- B. addition of two π -electrons to give $C_9H_{10}^{2-}$
- C. loss of H^+ from the sp^3 -hybridized carbon to give $C_9H_9^-$**
- D. loss of H^+ from an sp^2 -hybridized carbon to give $C_9H_9^-$
- E. loss of $:H^-$ from the sp^3 -hybridized carbon to give $C_9H_9^+$

Self Test Question

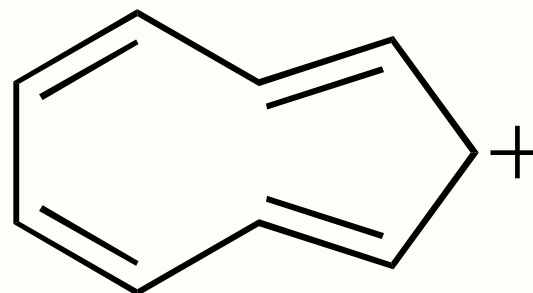
With respect to cyclononatetraene, which process below will form an aromatic species?



- A. addition of one π -electron to give $C_9H_{10}^-$
- B. addition of two π -electrons to give $C_9H_{10}^{2-}$
- C. loss of H^+ from the sp^3 -hybridized carbon to give $C_9H_9^-$
- D. loss of H^+ from an sp^2 -hybridized carbon to give $C_9H_9^-$
- E. loss of $:H^-$ from the sp^3 -hybridized carbon to give $C_9H_9^+$

Self Test Question

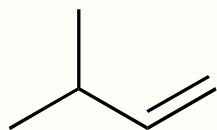
With respect to cyclononatetraene, which process below will form an aromatic species?



- A. addition of one π -electron to give $C_9H_{10}^-$
- B. addition of two π -electrons to give $C_9H_{10}^{2-}$
- C. loss of H^+ from the sp^3 -hybridized carbon to give $C_9H_9^-$
- D. loss of H^+ from an sp^2 -hybridized carbon to give $C_9H_9^-$
- E. loss of $:H^-$ from the sp^3 -hybridized carbon to give $C_9H_9^+$

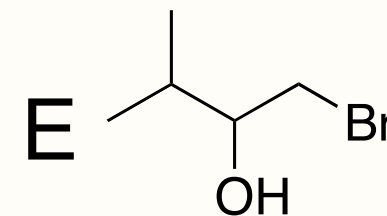
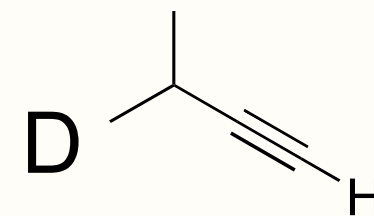
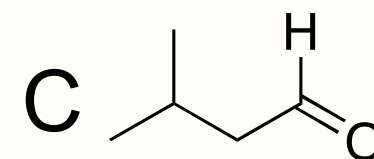
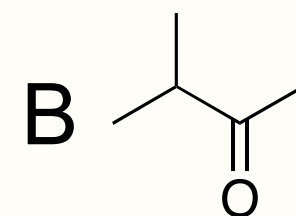
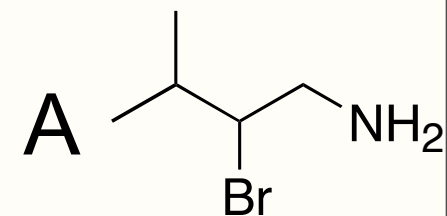
Self Test Question

Predict the product.



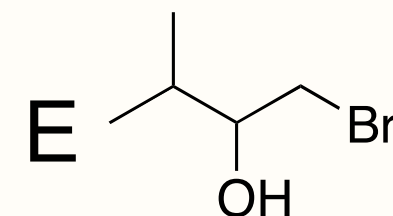
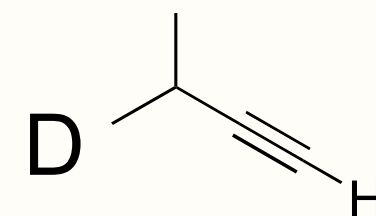
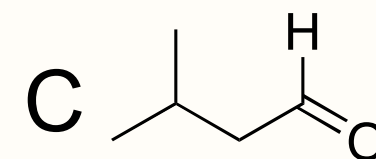
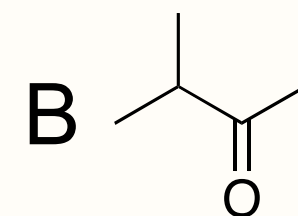
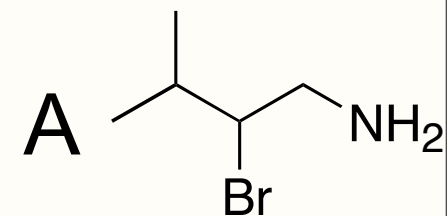
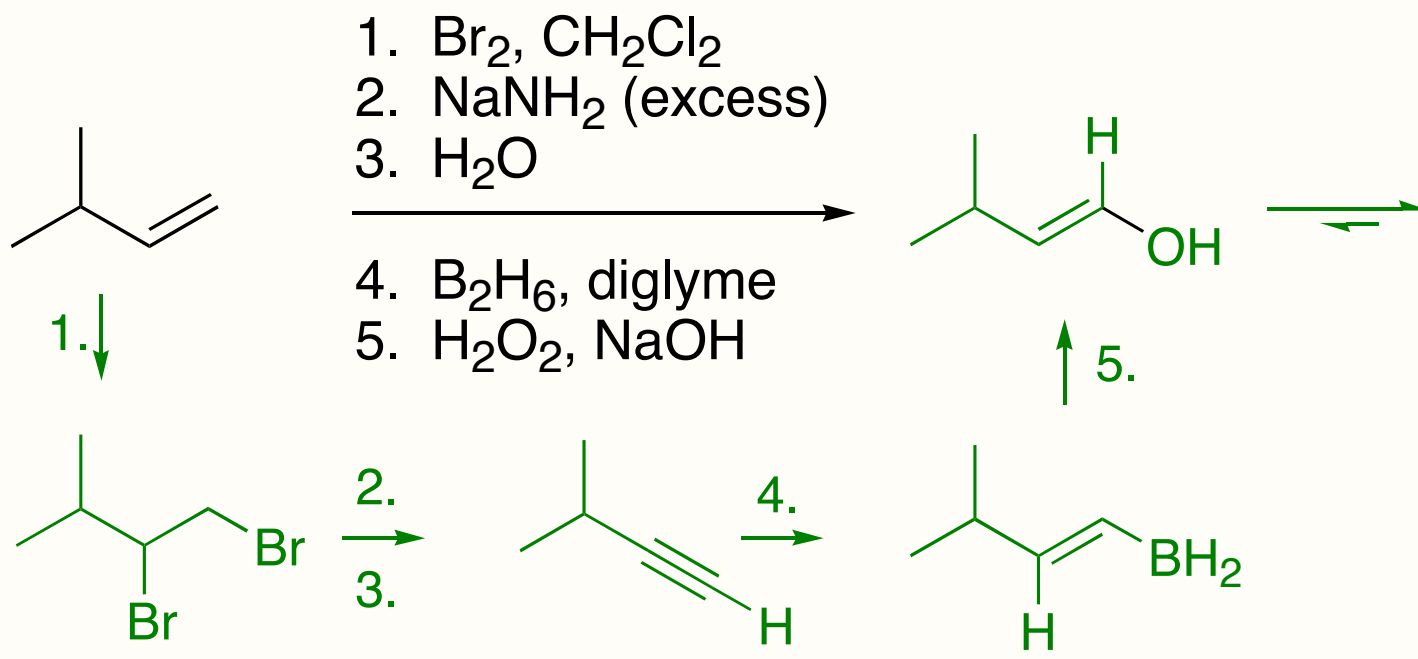
1. Br_2 , CH_2Cl_2
2. NaNH_2 (excess)
3. H_2O

-
4. B_2H_6 , diglyme
 5. H_2O_2 , NaOH



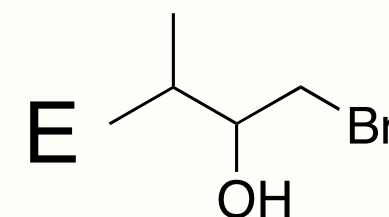
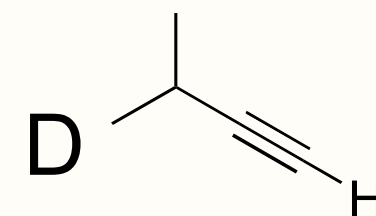
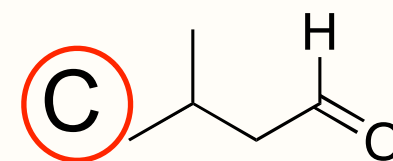
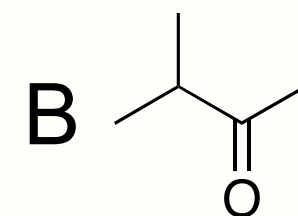
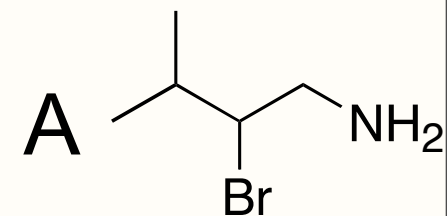
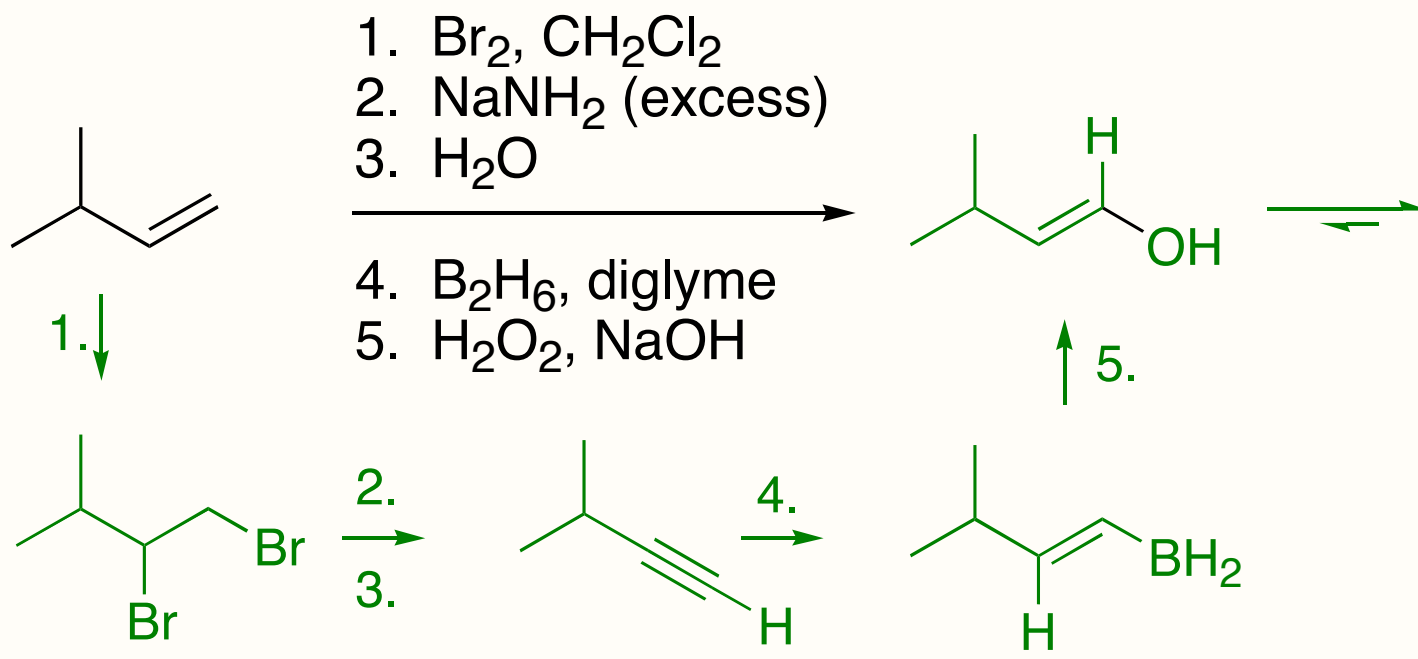
Self Test Question

Predict the product.

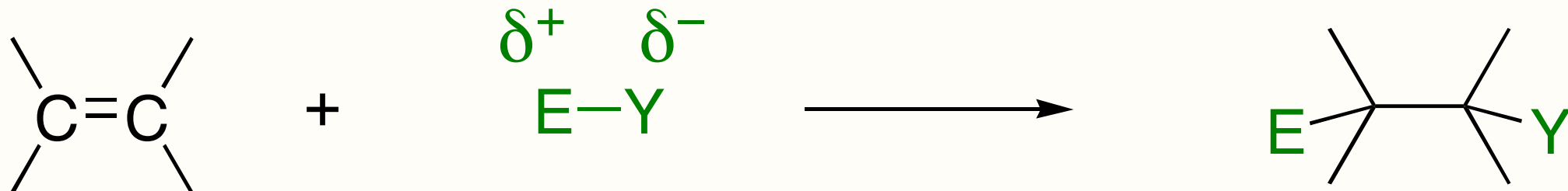


Self Test Question

Predict the product.



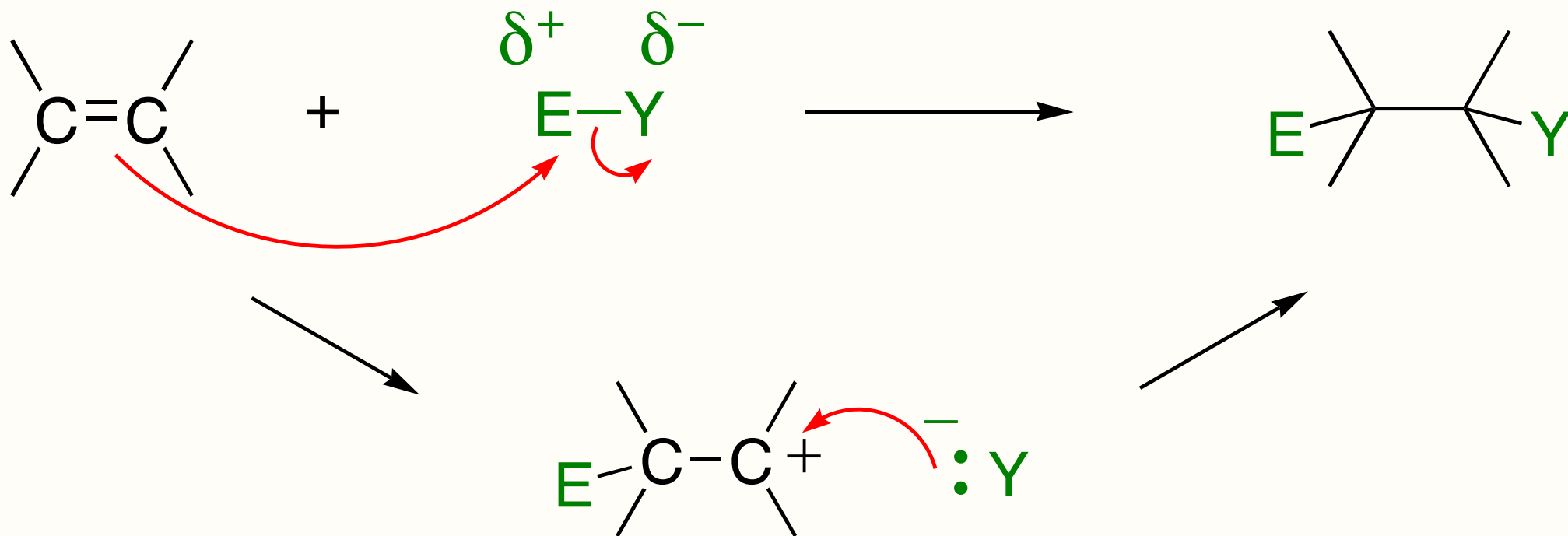
Review: Addition Reactions to Alkenes



Electrophilic Addition (Ad_E)

- In all addition reactions, the alkene is the nucleophile (Lewis base: weakly held π -electrons are used/donated to form stronger s-bonds).
- Reagent being added to the alkene is an electrophile (Lewis acid: accepting electrons to form s-bonds).

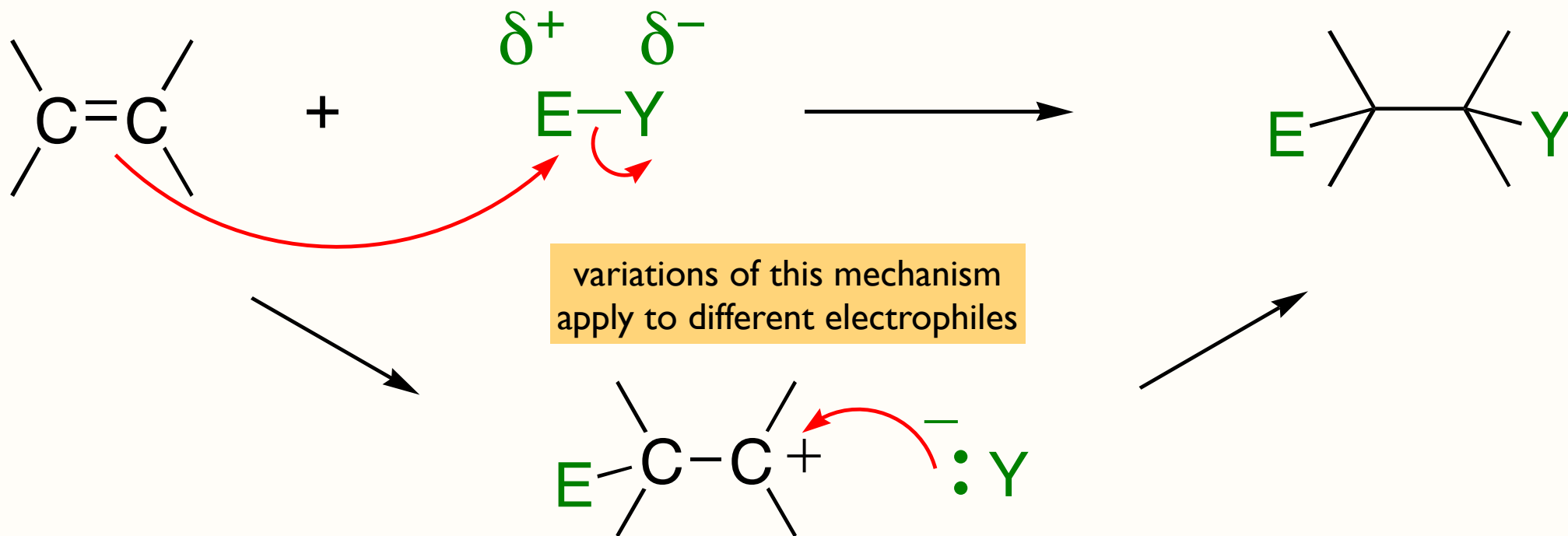
Review: Addition Reactions to Alkenes



Electrophilic Addition (Ad_E)

- In all addition reactions, the alkene is the nucleophile (Lewis base: weakly held π -electrons are used/donated to form stronger s -bonds).
- Reagent being added to the alkene is an electrophile (Lewis acid: accepting electrons to form s -bonds).

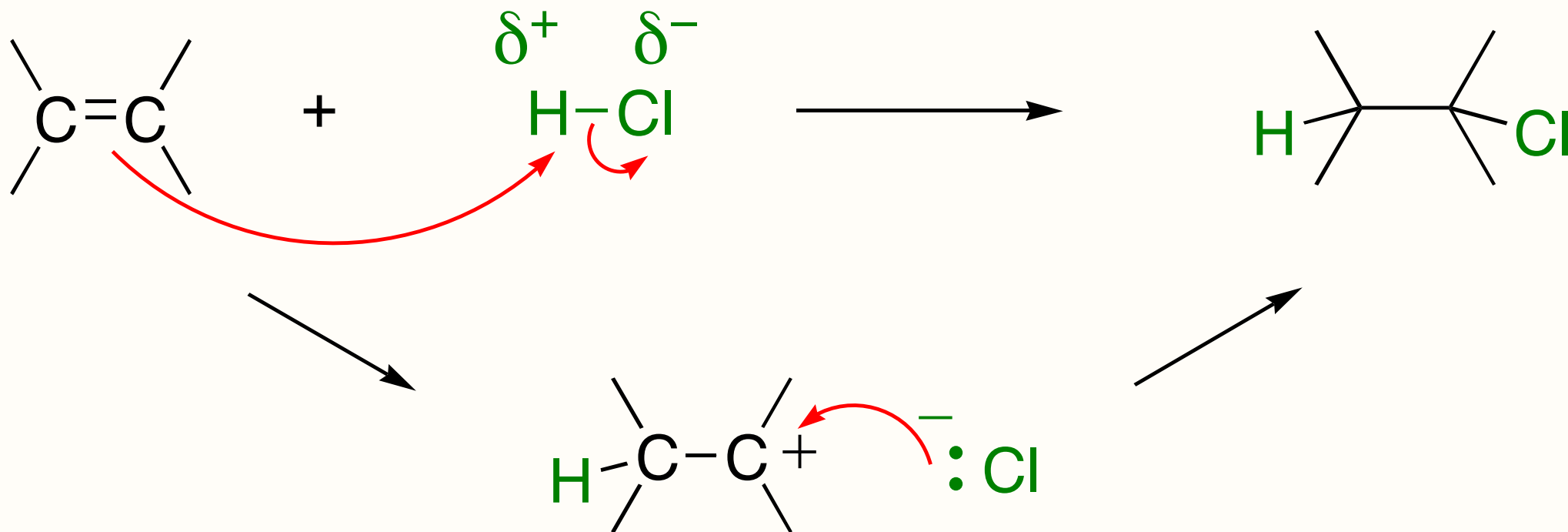
Review: Addition Reactions to Alkenes



Electrophilic Addition (Ad_E)

- In all addition reactions, the alkene is the nucleophile (Lewis base: weakly held π -electrons are used/donated to form stronger s -bonds).
- Reagent being added to the alkene is an electrophile (Lewis acid: accepting electrons to form s -bonds).

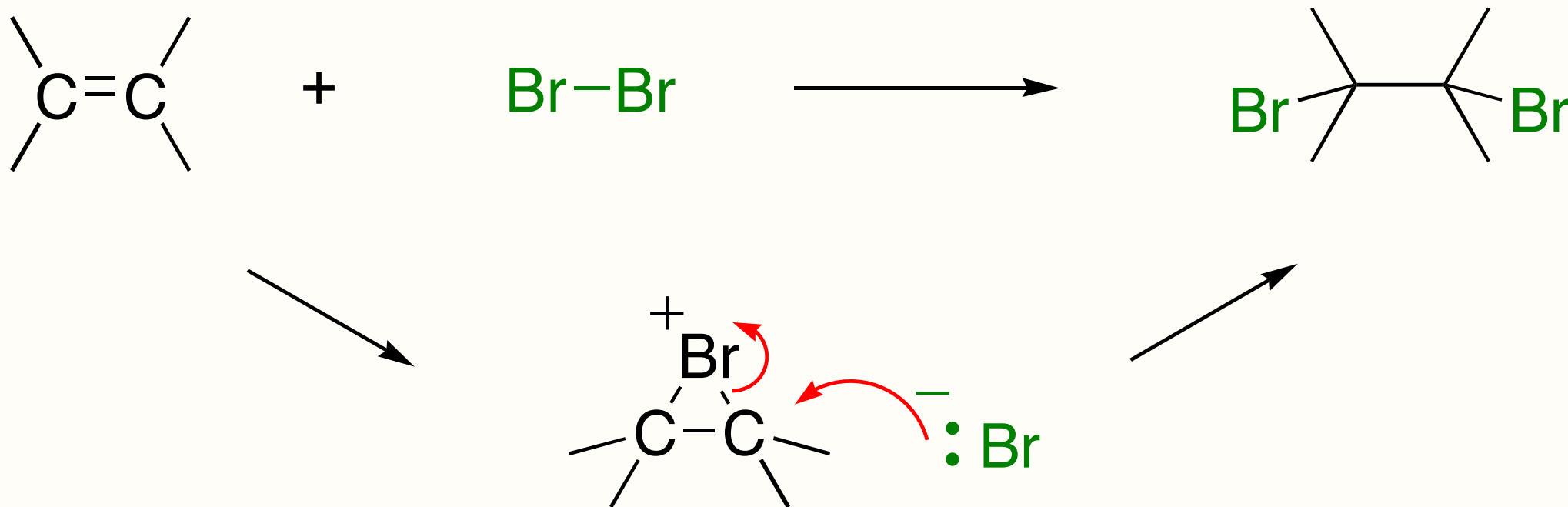
Review: Addition Reactions to Alkenes



Electrophilic Addition (A_{dE})

- In all addition reactions, the alkene is the nucleophile (Lewis base: weakly held π -electrons are used/donated to form stronger σ -bonds).
- Reagent being added to the alkene is an electrophile (Lewis acid: accepting electrons to form σ -bonds).

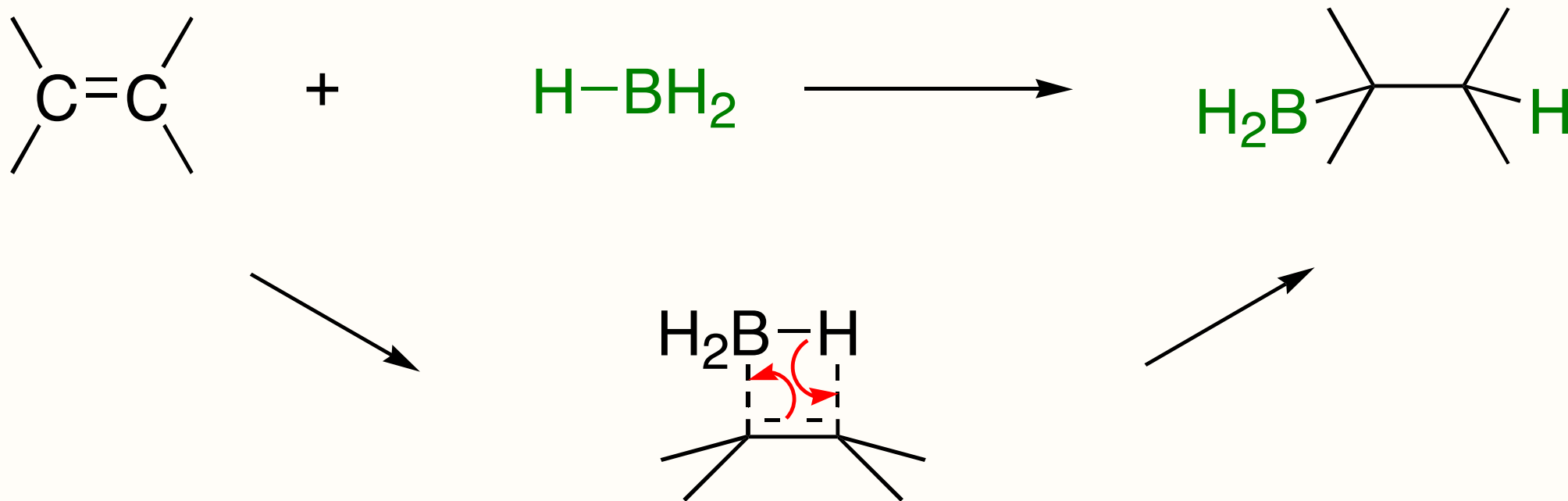
Review: Addition Reactions to Alkenes



Electrophilic Addition (A_{dE})

- In all addition reactions, the alkene is the nucleophile (Lewis base: weakly held π -electrons are used/donated to form stronger σ -bonds).
- Reagent being added to the alkene is an electrophile (Lewis acid: accepting electrons to form σ -bonds).

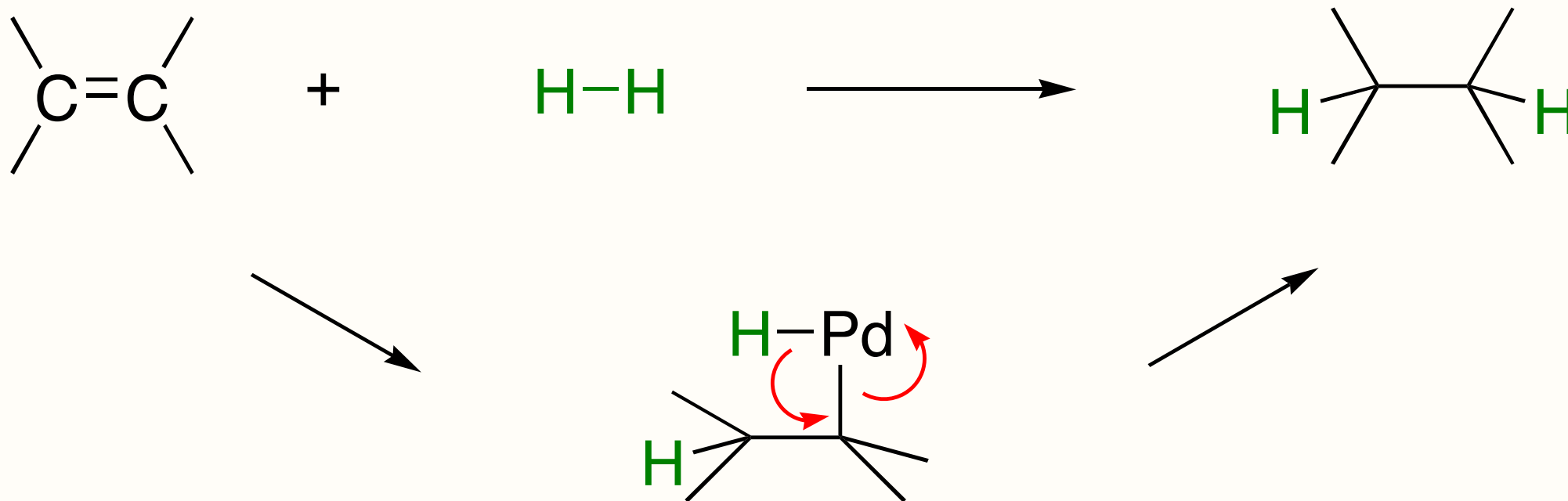
Review: Addition Reactions to Alkenes



Electrophilic Addition (Ad_E)

- In all addition reactions, the alkene is the nucleophile (Lewis base: weakly held π -electrons are used/donated to form stronger σ -bonds).
- Reagent being added to the alkene is an electrophile (Lewis acid: accepting electrons to form σ -bonds).

Review: Addition Reactions to Alkenes

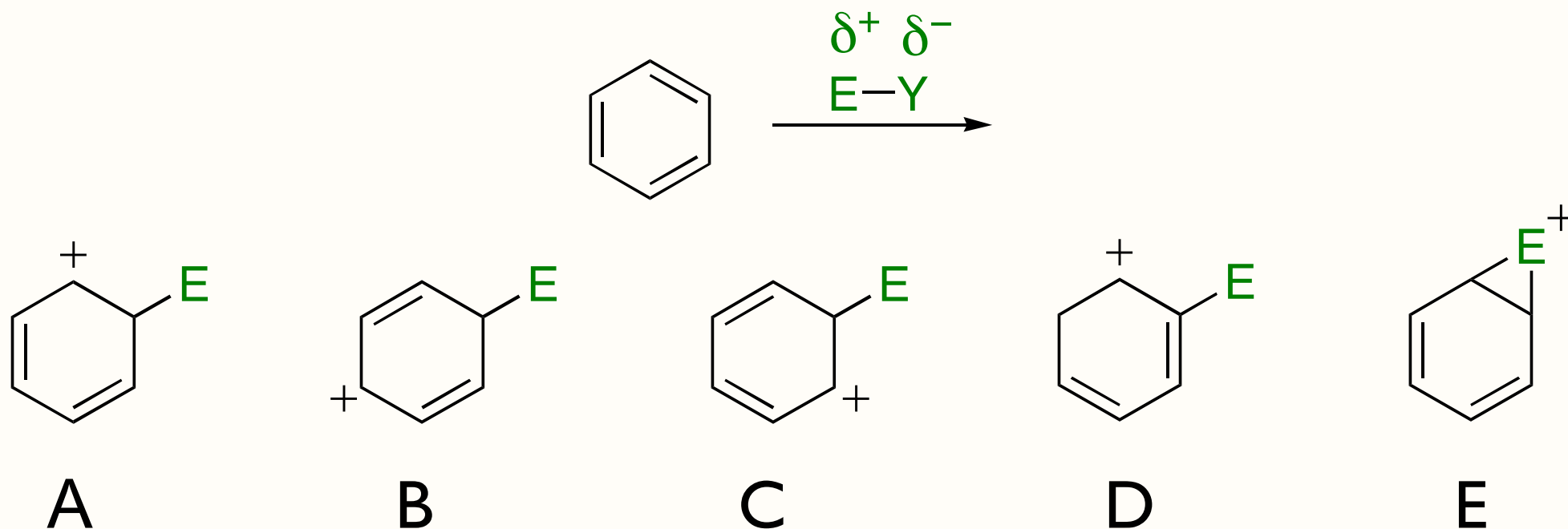


Electrophilic Addition (A_{E})

- In all addition reactions, the alkene is the nucleophile (Lewis base: weakly held π -electrons are used/donated to form stronger s-bonds).
- Reagent being added to the alkene is an electrophile (Lewis acid: accepting electrons to form s-bonds).

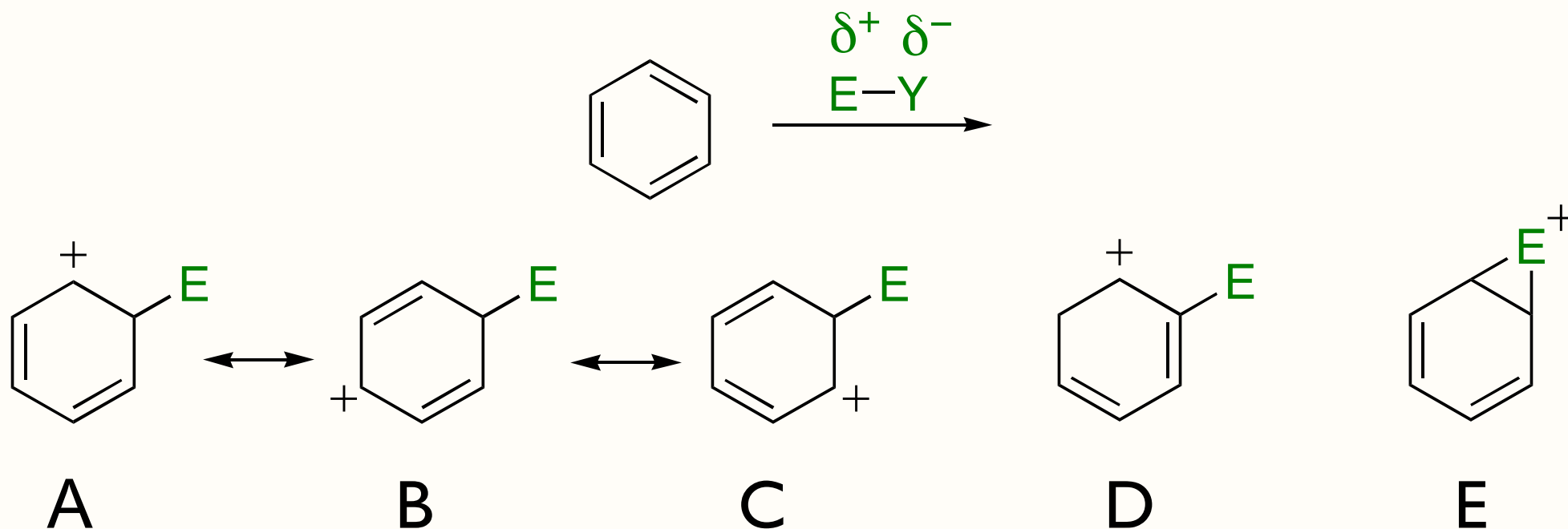
Self Test Question

Assuming that benzene reacts similarly to alkenes, which structure could *not* be an intermediate for A_{dE} with the general electrophile depicted?



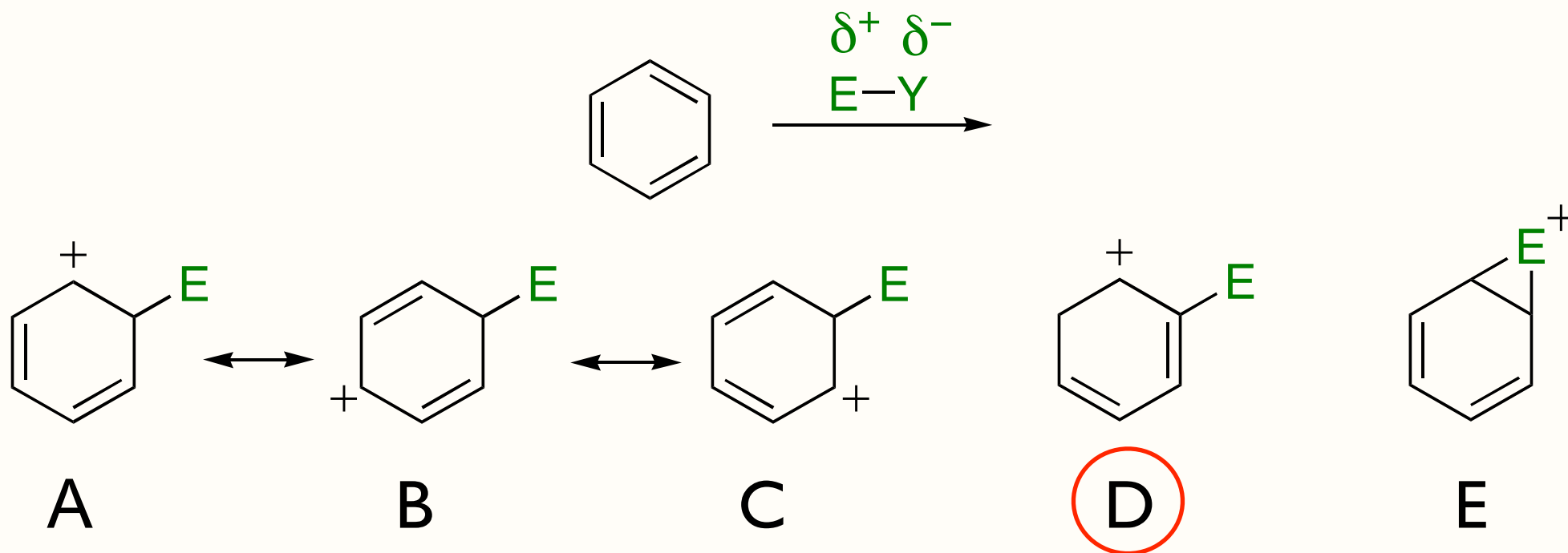
Self Test Question

Assuming that benzene reacts similarly to alkenes, which structure could *not* be an intermediate for A_{dE} with the general electrophile depicted?

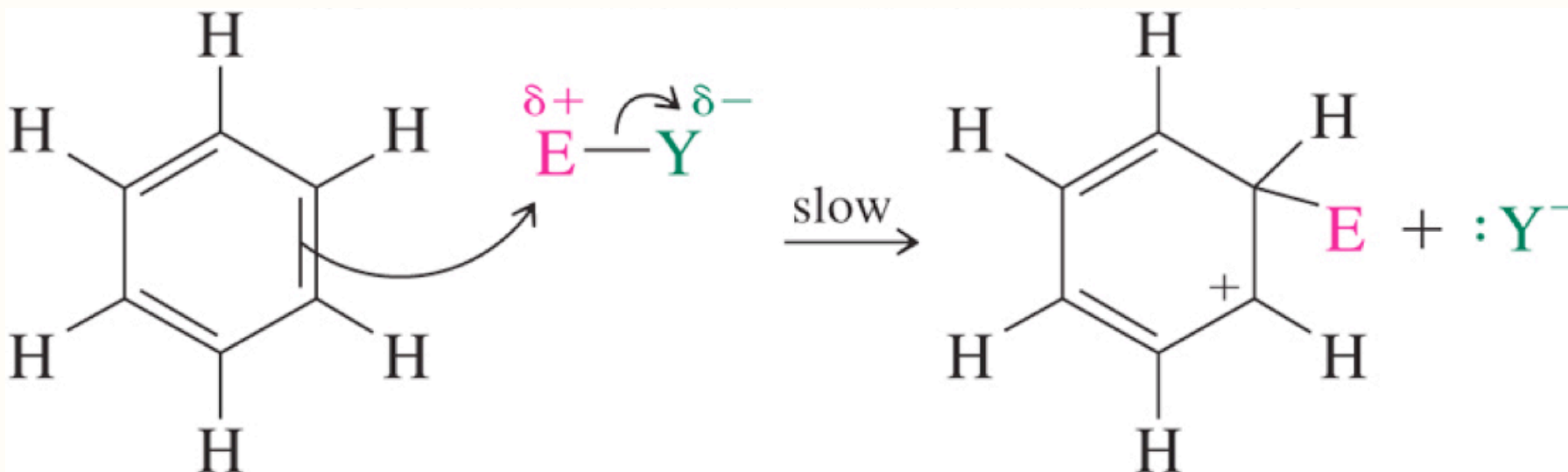


Self Test Question

Assuming that benzene reacts similarly to alkenes, which structure could *not* be an intermediate for A_{dE} with the general electrophile depicted?

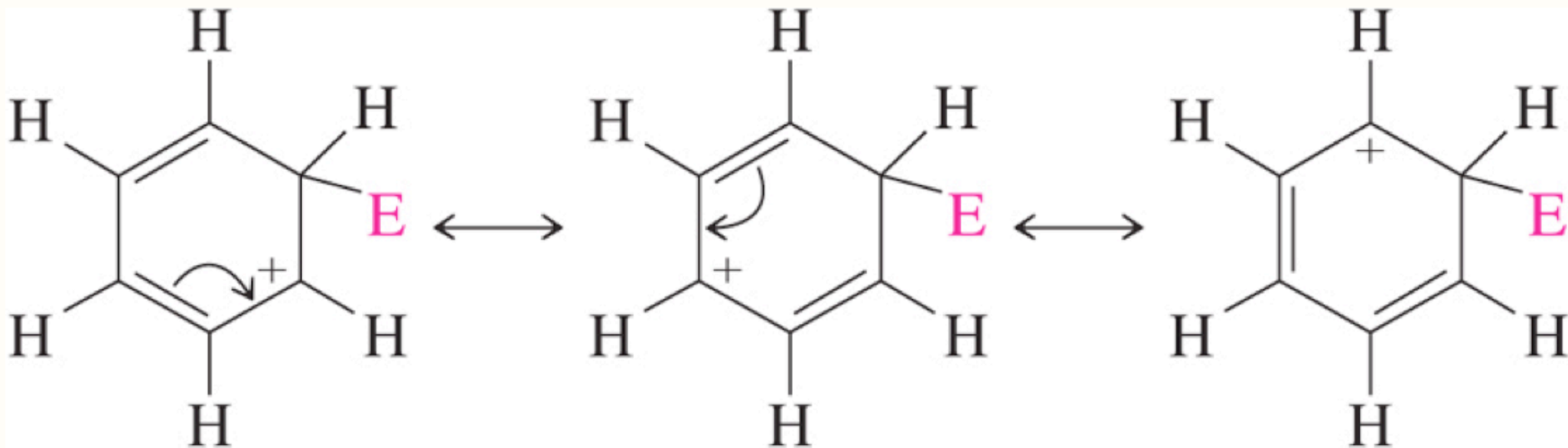


Formation of Arenium Ion



- **arenium ion:** carbocation formed from an aromatic ring
- formation of arenium ions is slow since the ground state is so stable (loss of aromaticity)
- requires very reactive (high energy) electrophiles

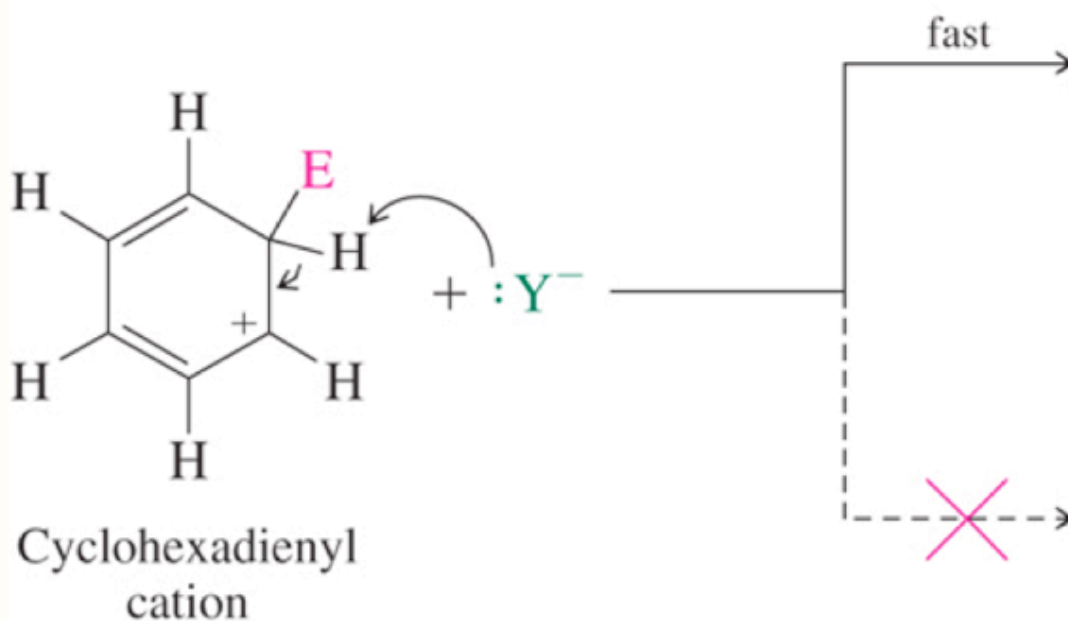
Arenium Ions



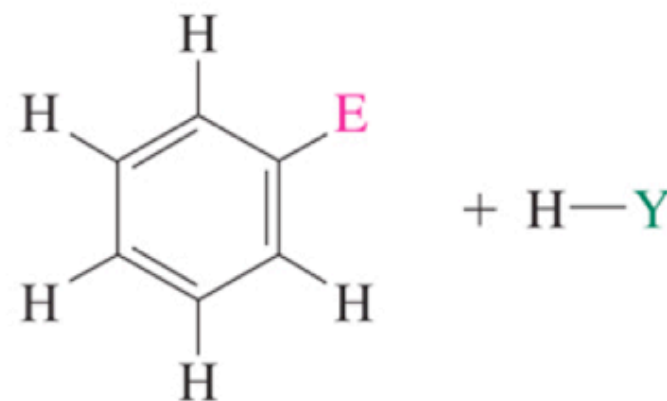
- **arenium ion:** also known as a σ -complex
- arenium ions are allylic carbocations
- stabilized by resonance
- no aromatic

Fate of Arenium Ion

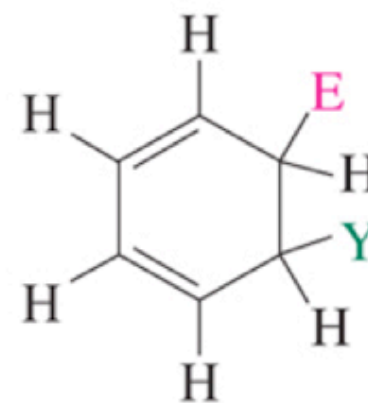
Electrophilic aromatic substitution (S_{E2Ar})



Product of electrophilic aromatic substitution



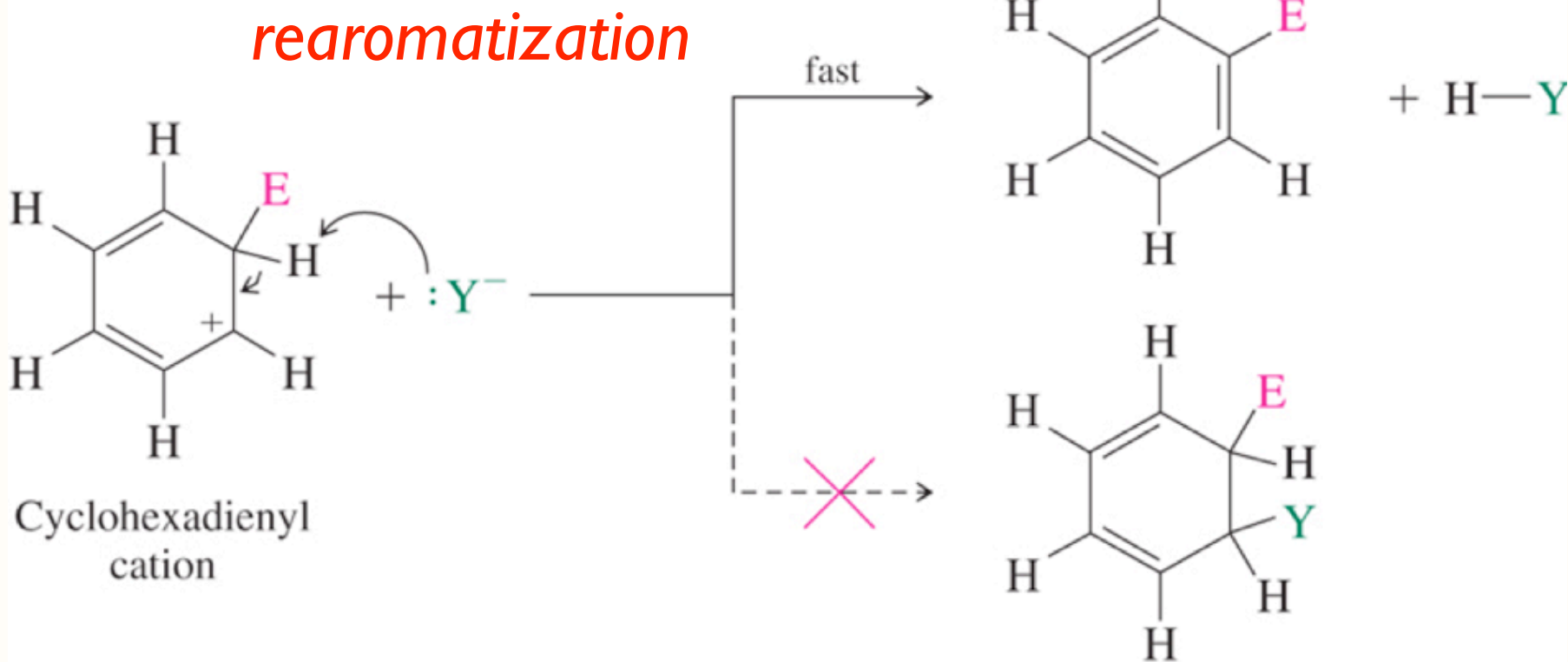
Electrophilic addition (Ad_{E2Ar})



Not aromatic;
not formed

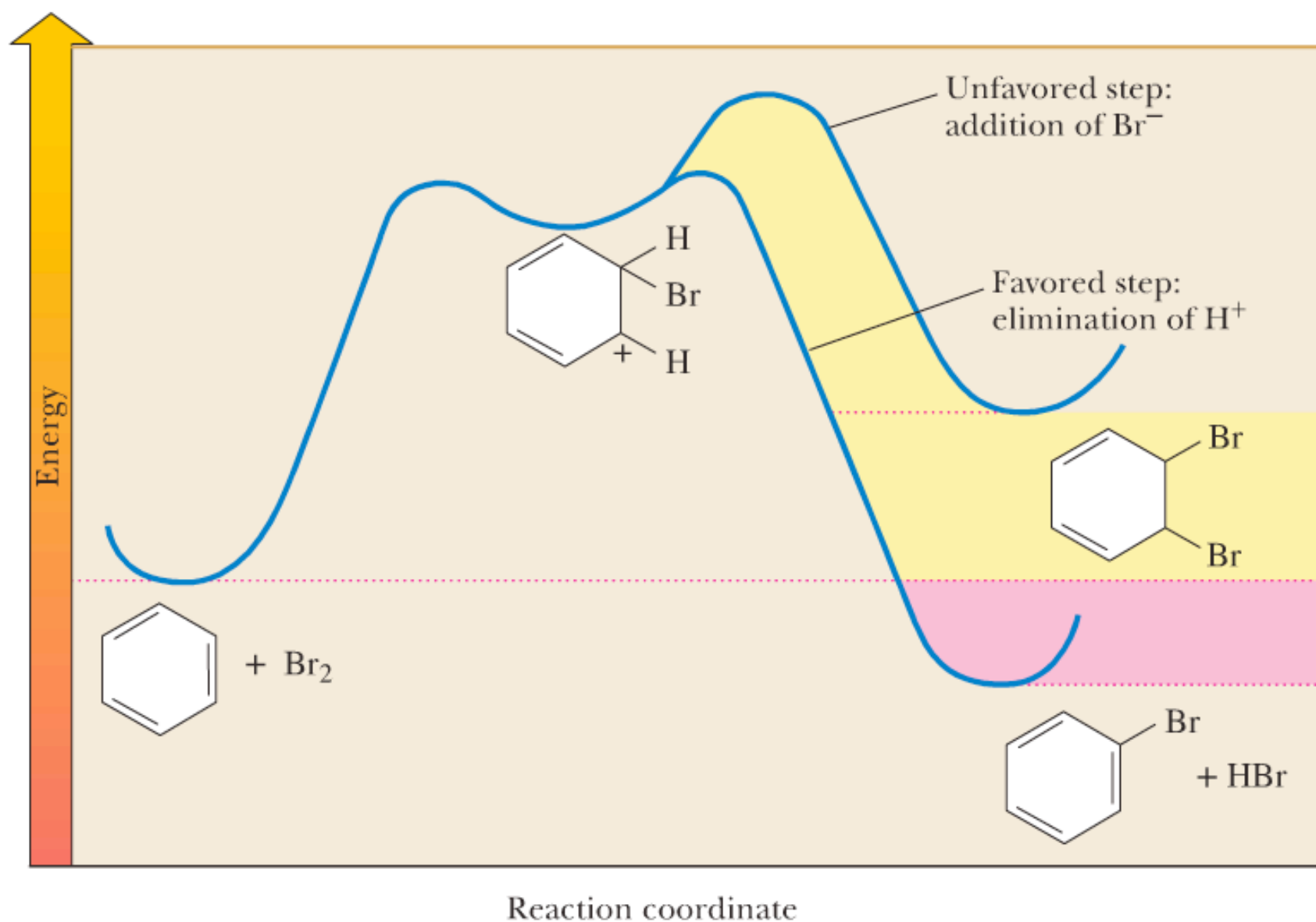
Fate of Arenium Ion

Electrophilic aromatic substitution (S_{E2Ar})



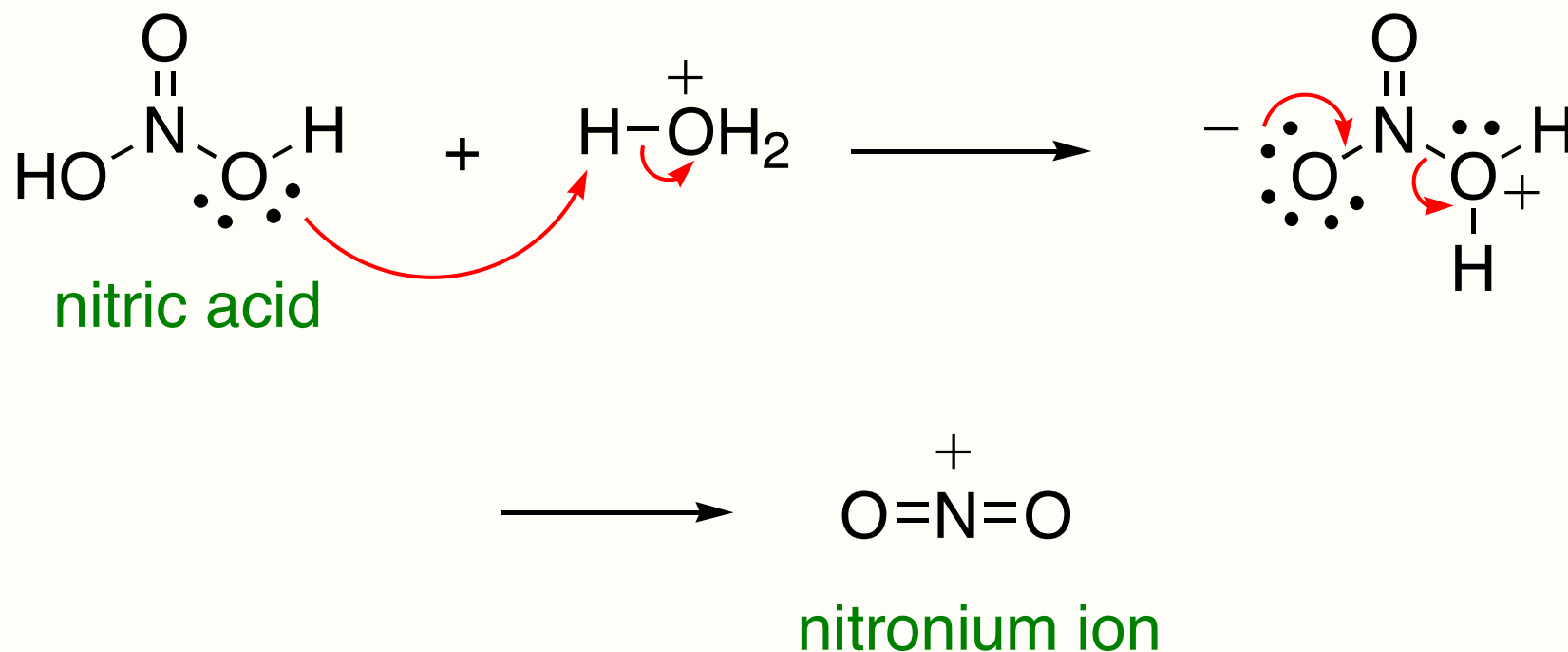
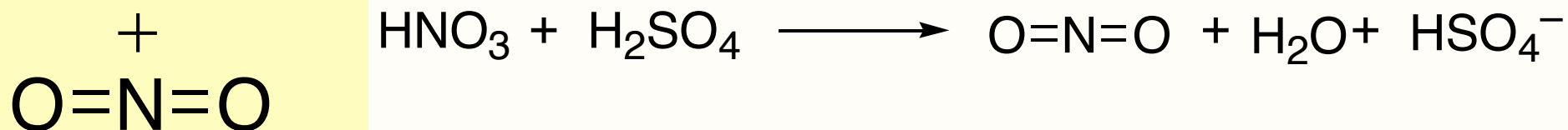
Electrophilic addition (Ad_{E2Ar})

Potential Energy Diagram

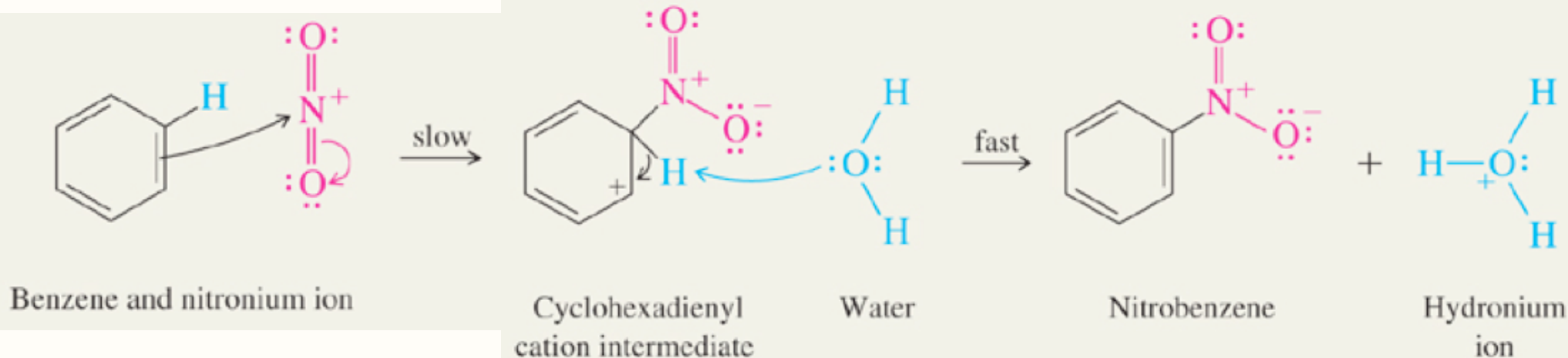
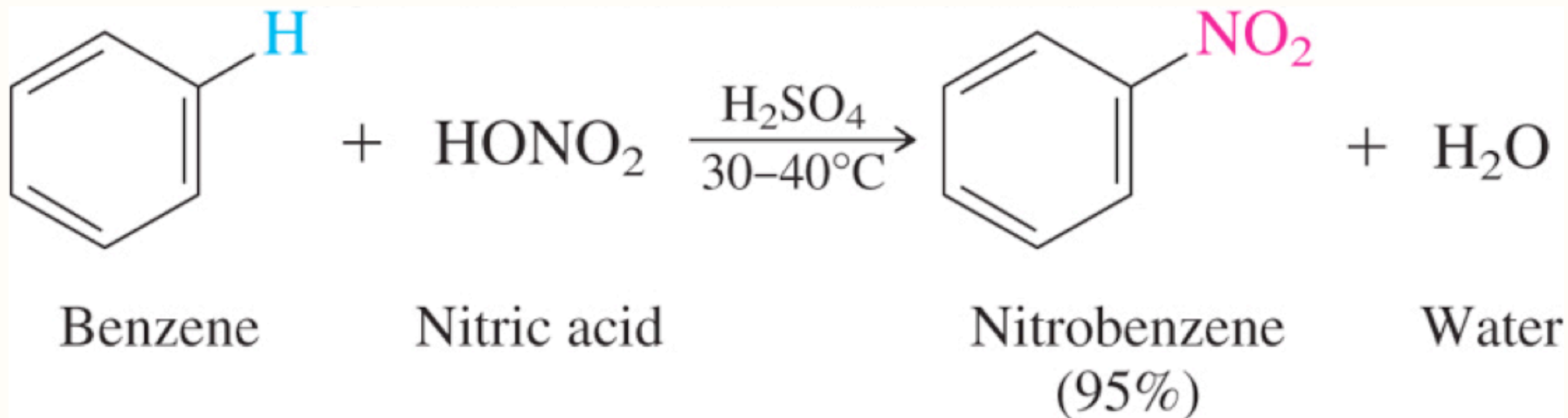


Preparation of Electrophiles

Nitronium Ion

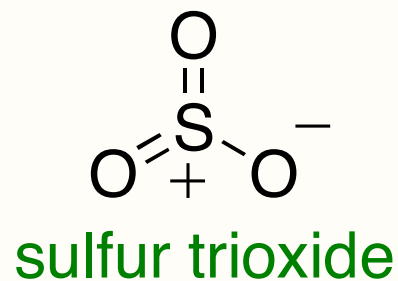
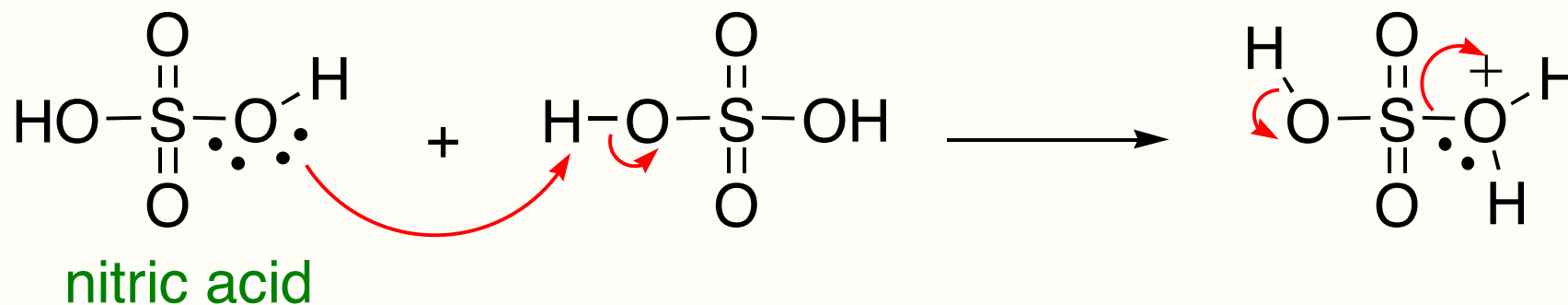
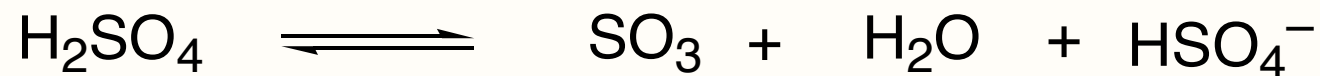
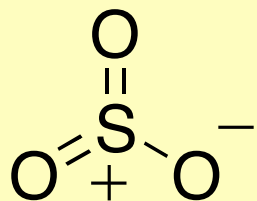


Nitration

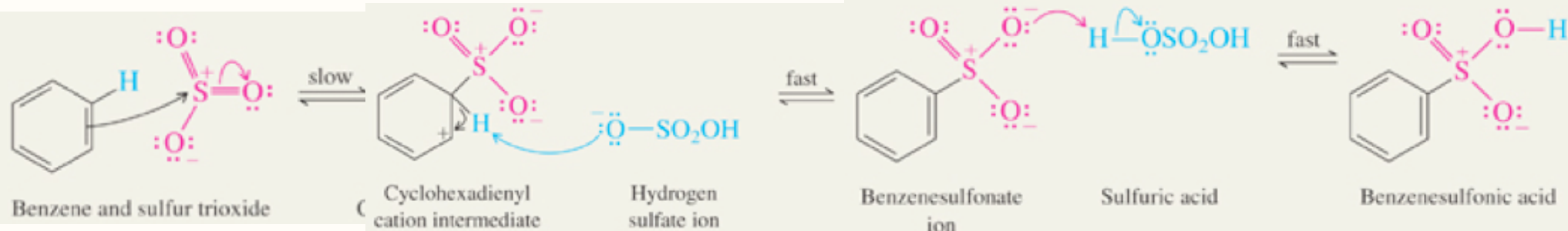
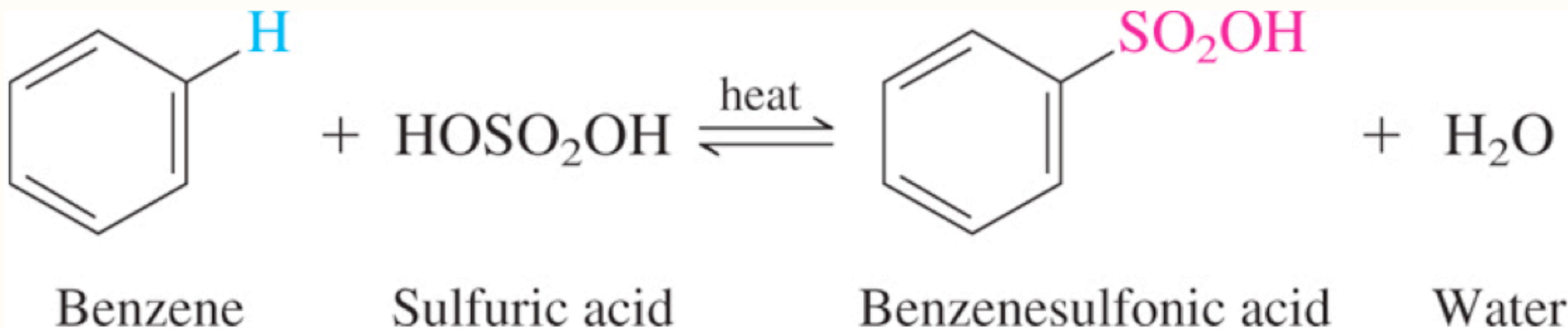


Preparation of Electrophiles

Sulfur trioxide

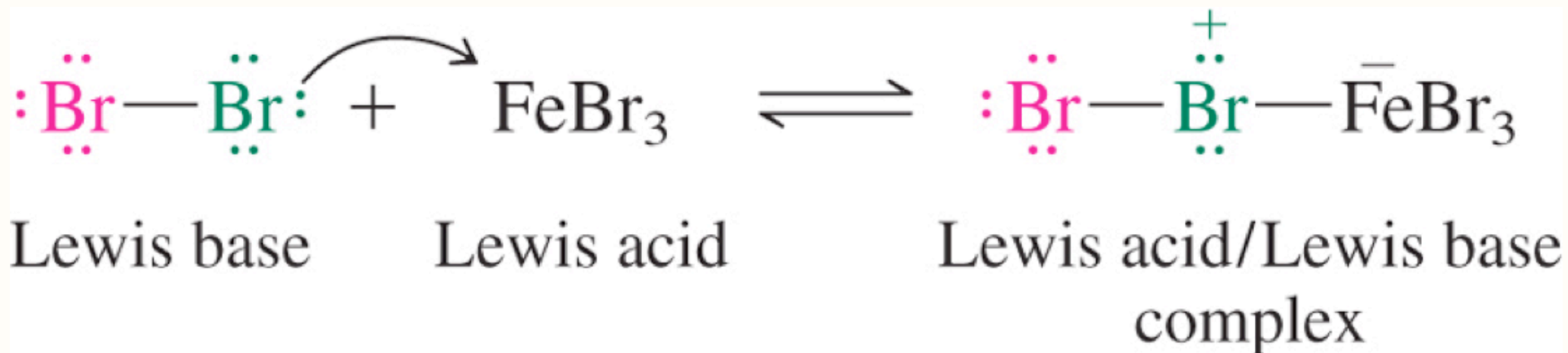
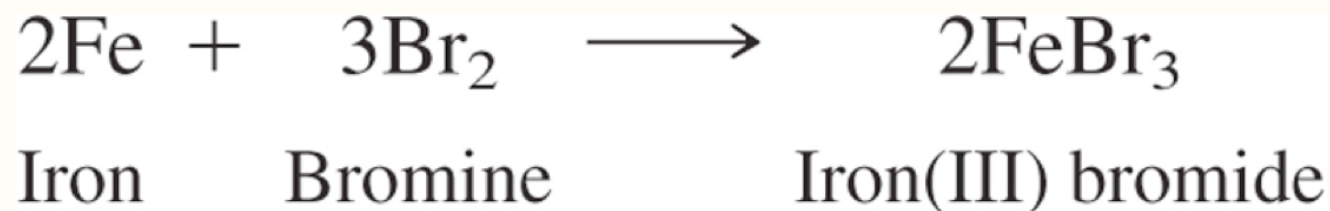


Sulfonation

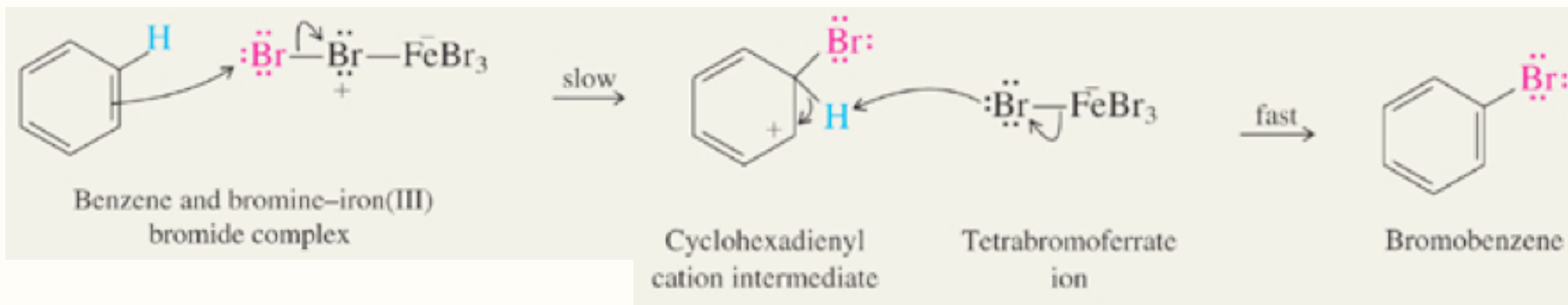
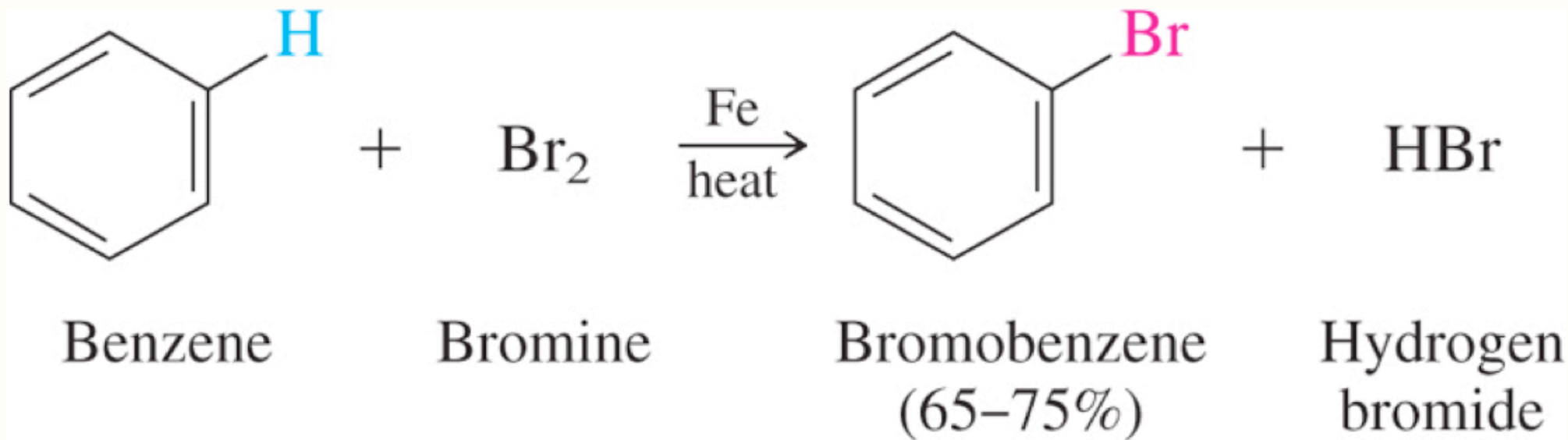


Preparation of Electrophiles

Bromine
complex

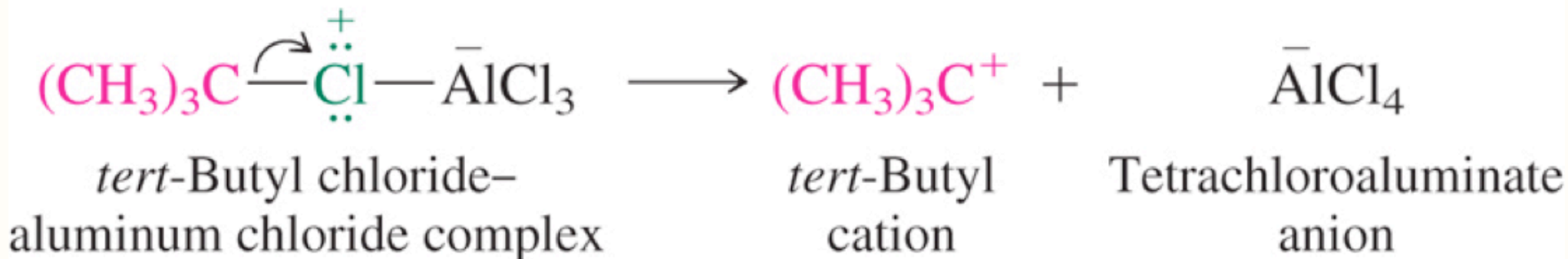
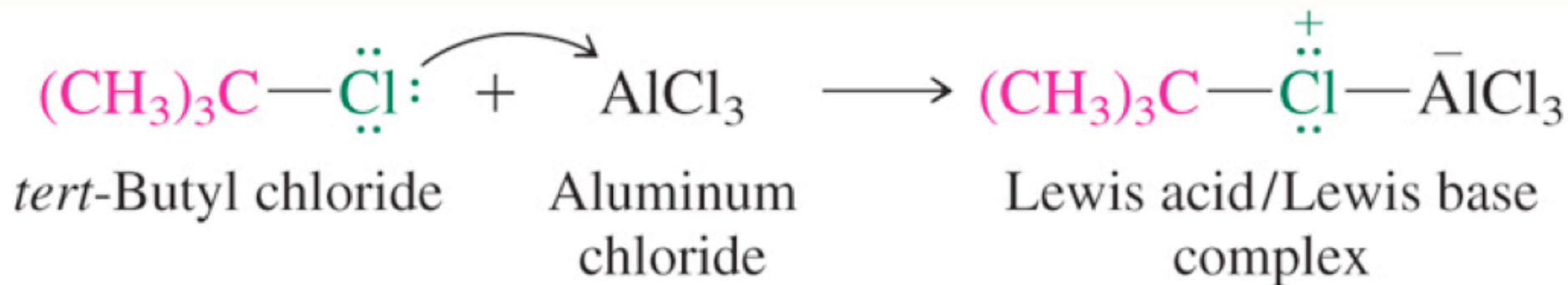
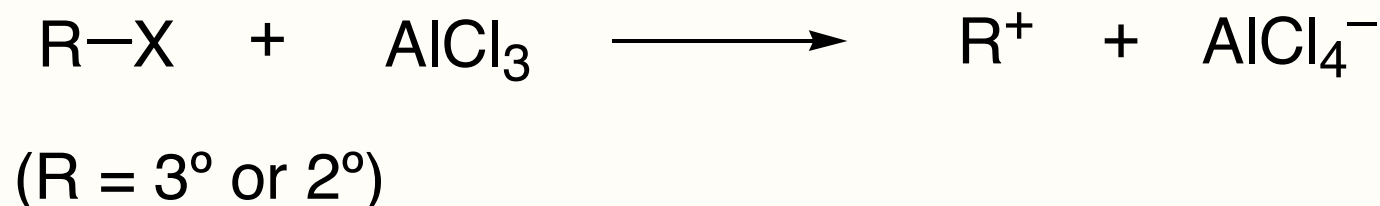


Bromination

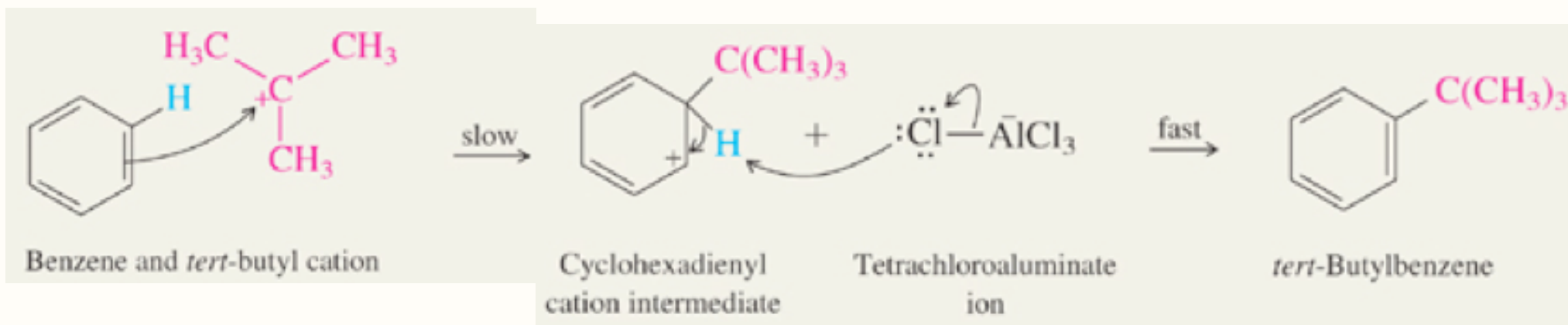
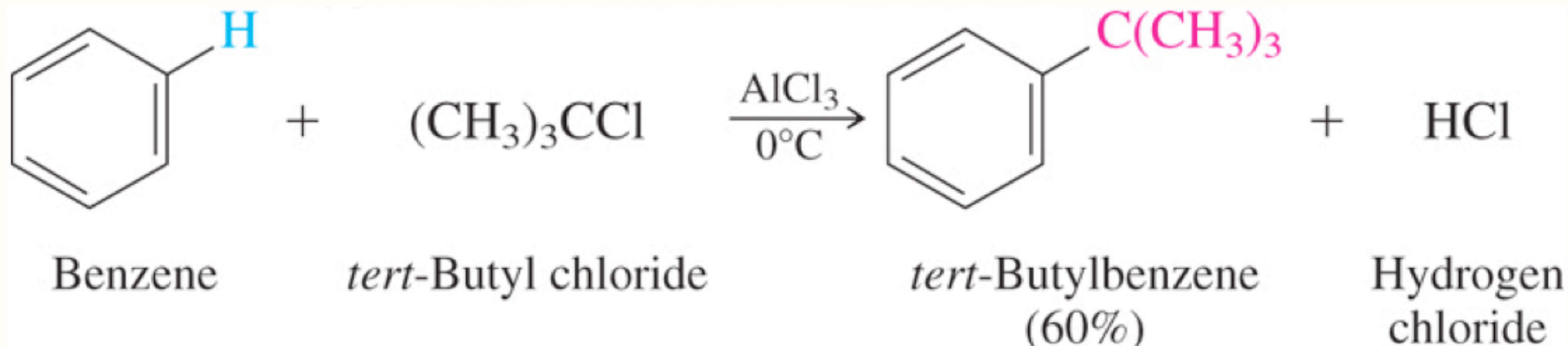


Preparation of Electrophiles

Carbocations

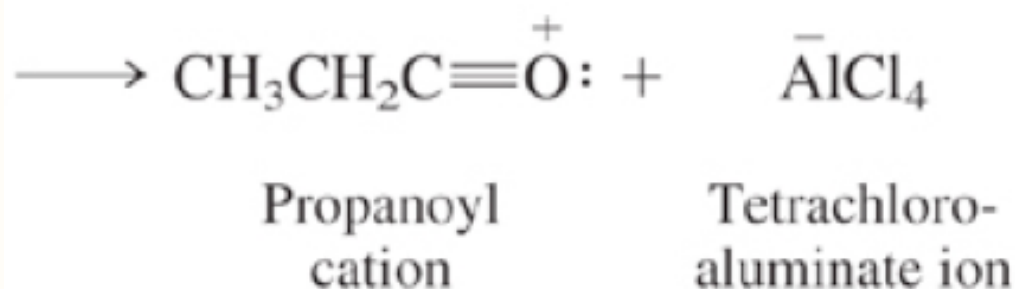
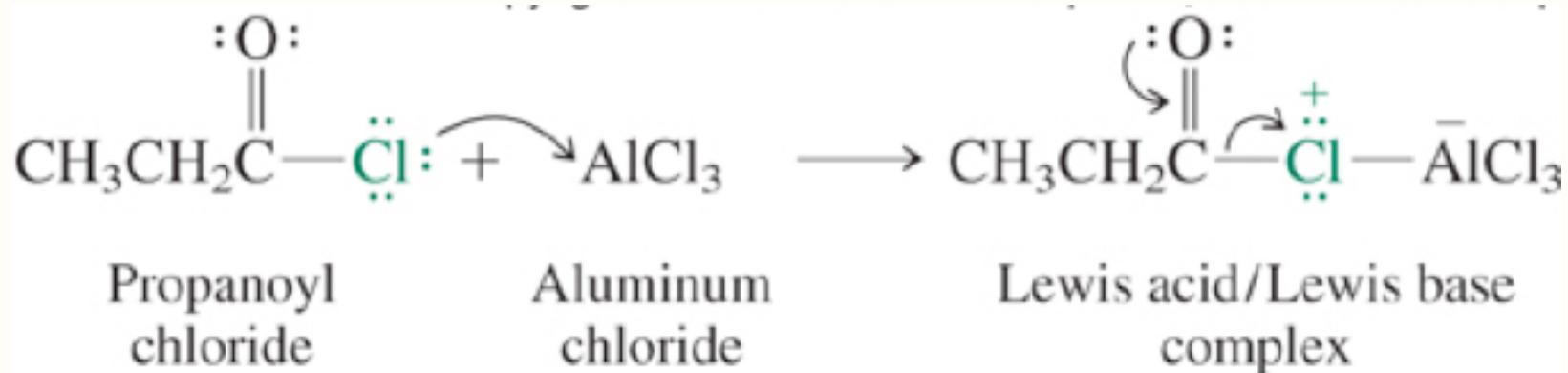
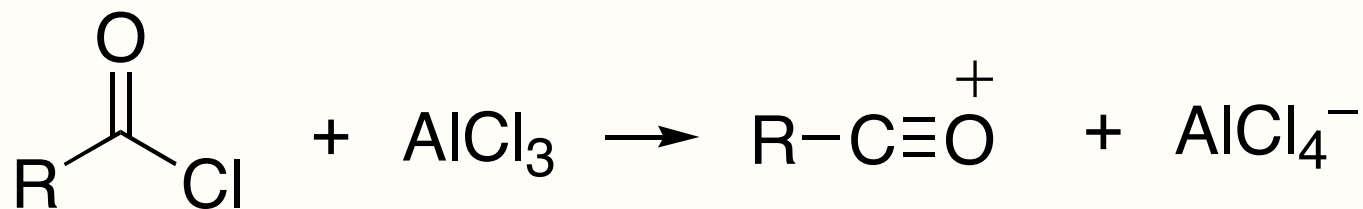
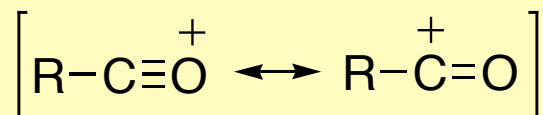


Friedel-Crafts Alkylation

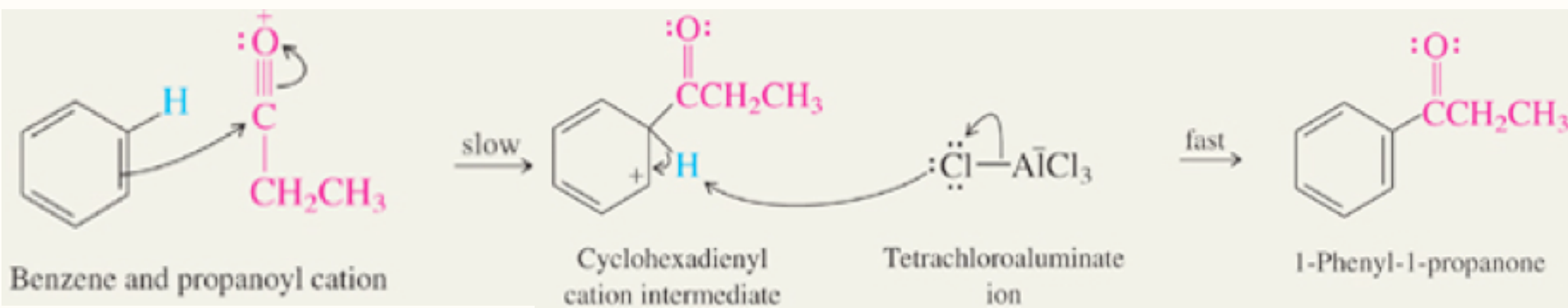
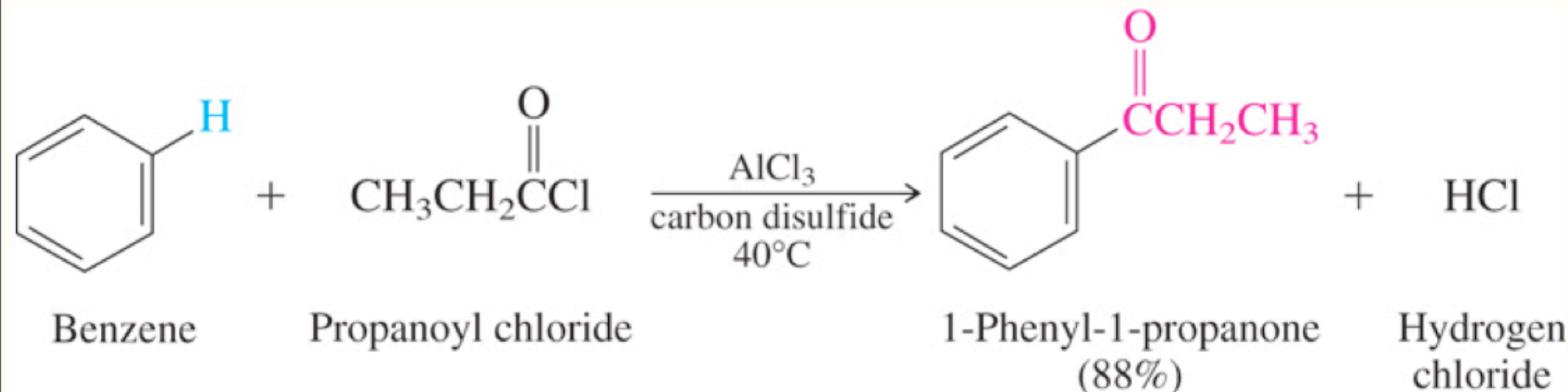


Preparation of Electrophiles

Acylium Ions

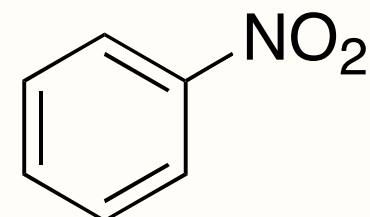
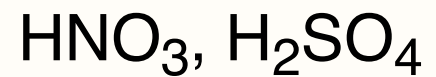
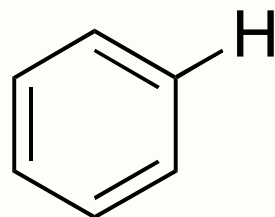


Friedel-Crafts Acylation

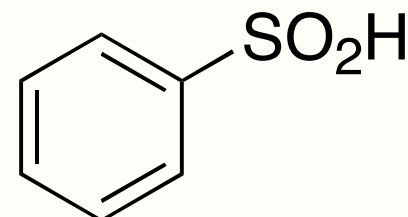
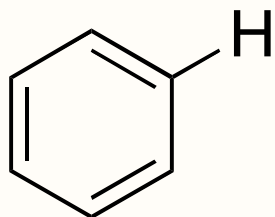


Summary of Some Representative Electrophilic Aromatic Substitutions

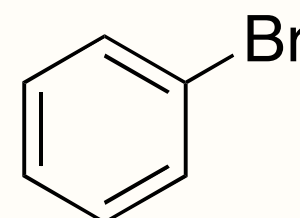
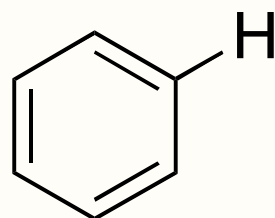
nitration



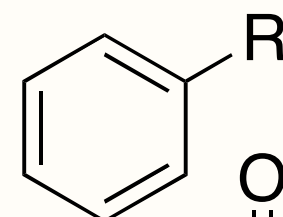
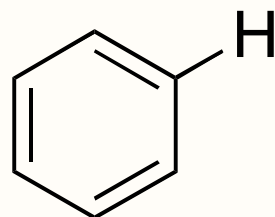
sulfonation



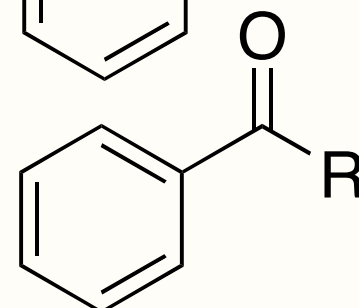
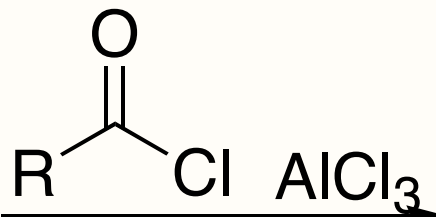
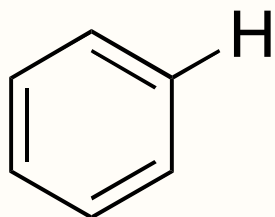
bromination



alkylation

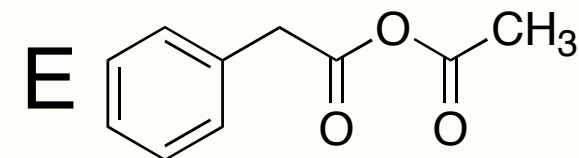
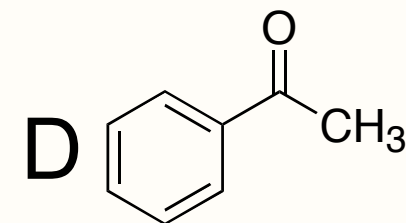
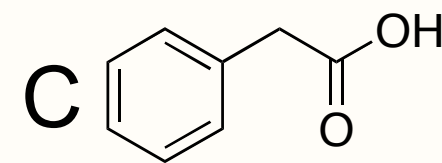
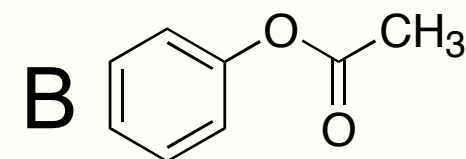
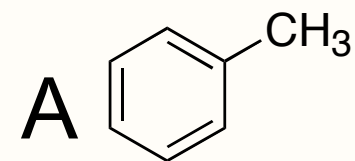
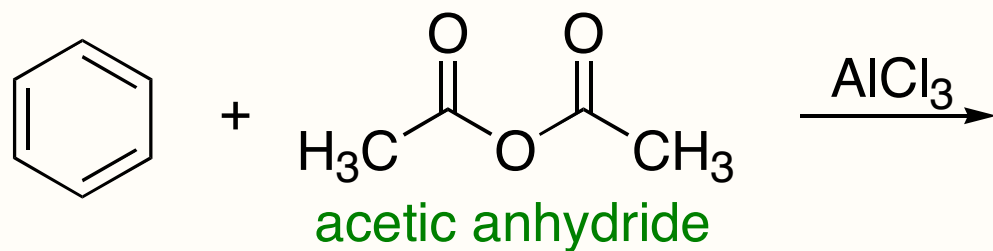


acylation



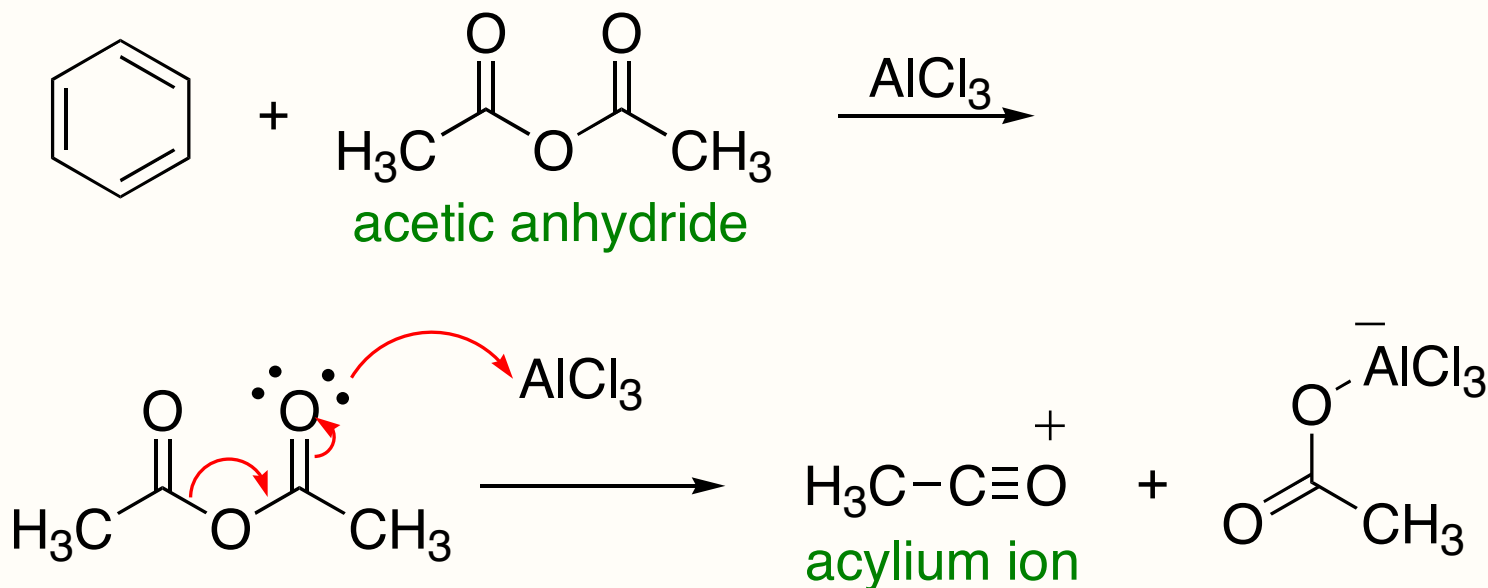
Self Test Question

If anhydrides also react with AlCl_3 to give acylium ions, what is the product for the acylation reaction below?



Self Test Question

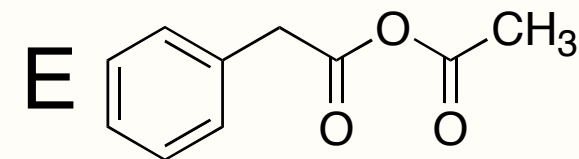
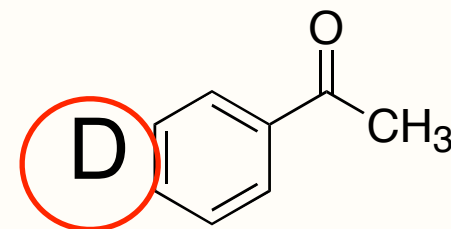
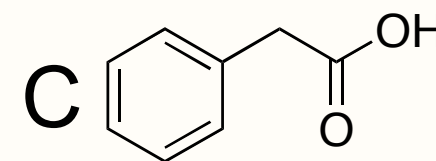
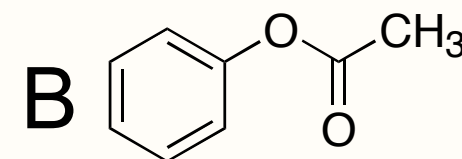
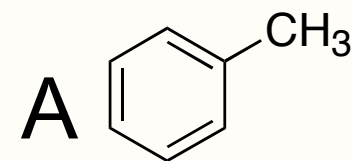
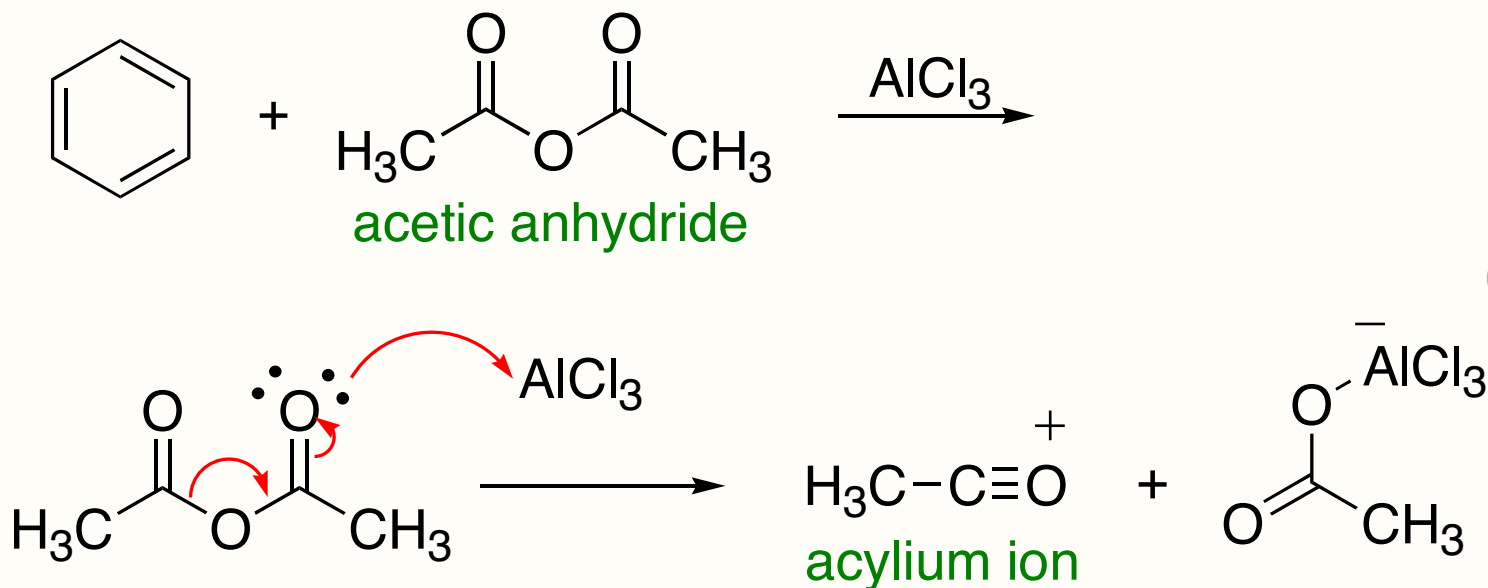
If anhydrides also react with AlCl_3 to give acylium ions, what is the product for the acylation reaction below?



- A
- B
- C
- D
- E

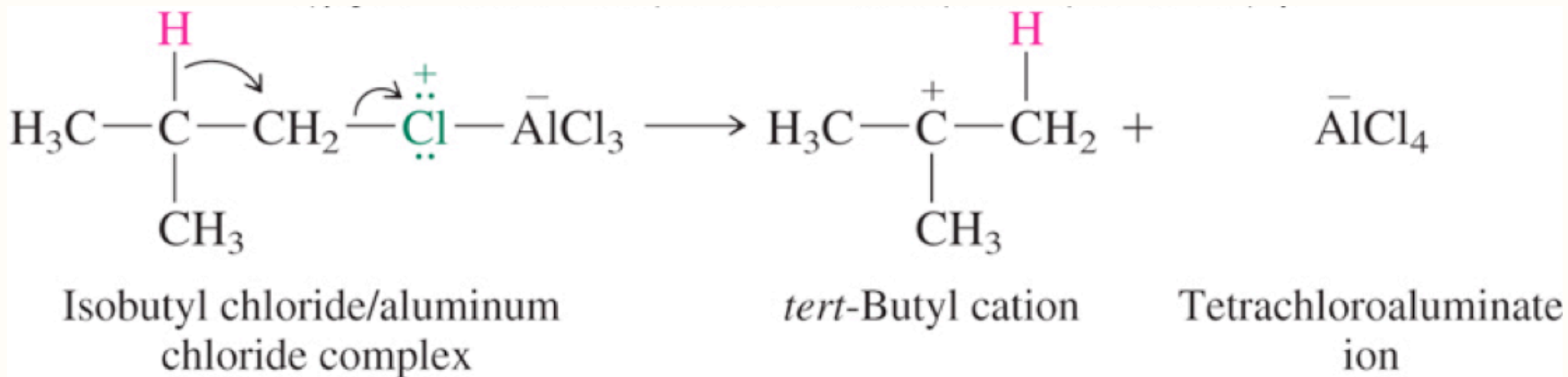
Self Test Question

If anhydrides also react with AlCl_3 to give acylium ions, what is the product for the acylation reaction below?



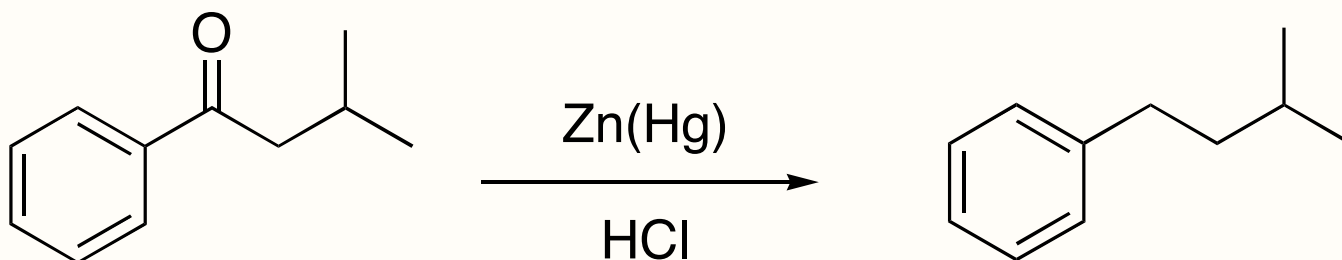
Complication of Friedel-Crafts Alkylations

- rearrangement to more stable carbocations always predominates
- 1° alkyl chlorides (except ethyl chloride) cannot be employed in FC alkylations

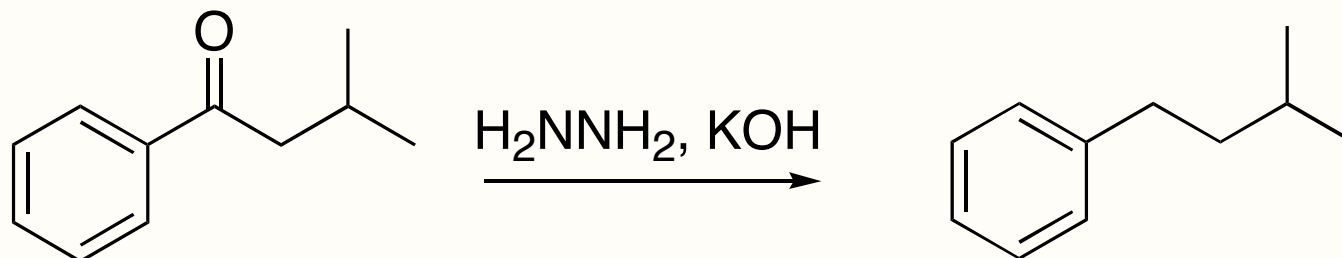


Reduction of Aryl Ketones

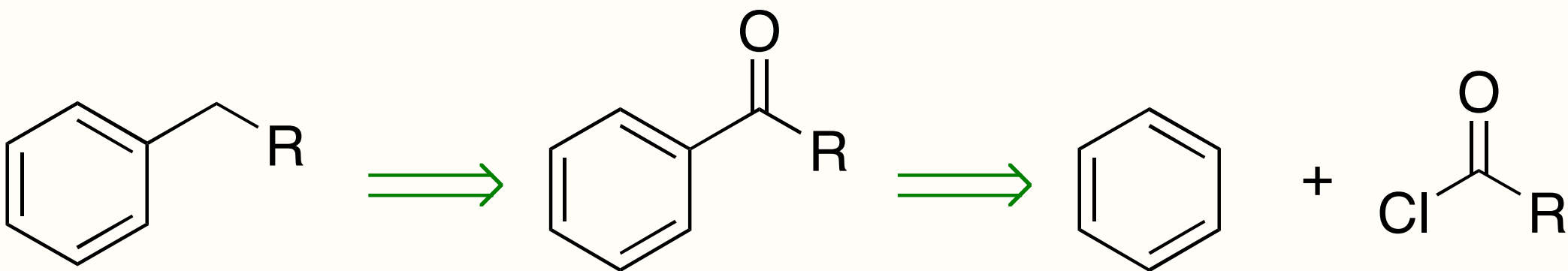
Clemmensen Reduction



Wolf-Kishner Reduction

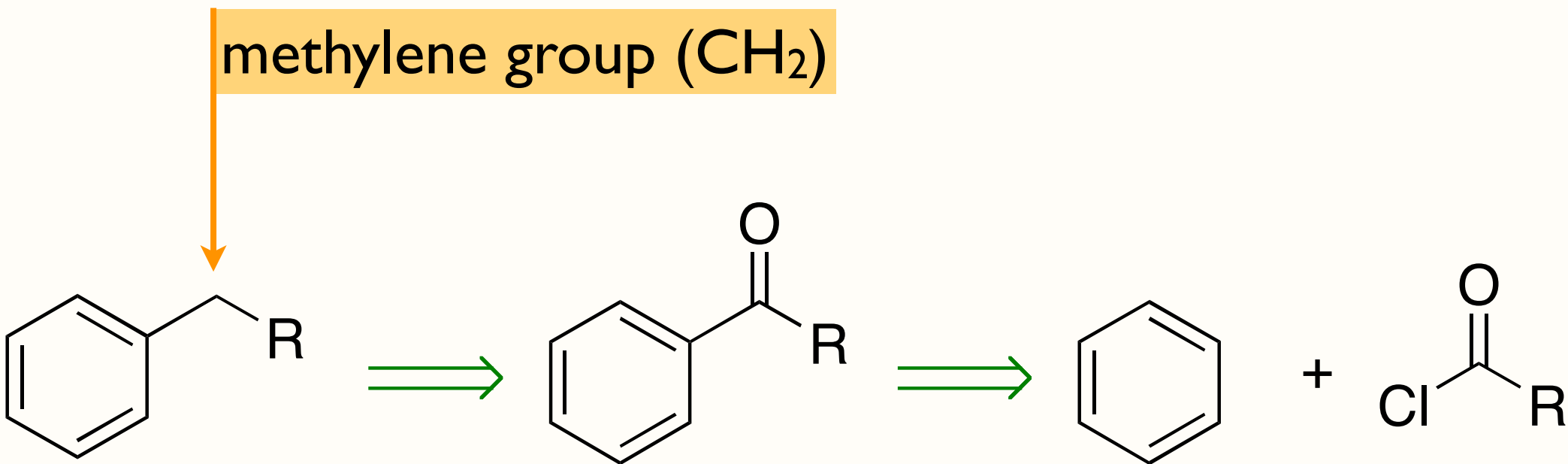


Alternative Strategy to Alkylbenzenes



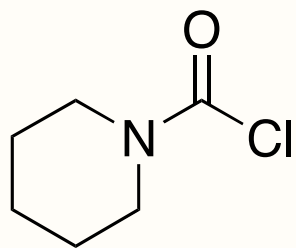
Alternative Strategy to Alkylbenzenes

methylene group (CH₂)

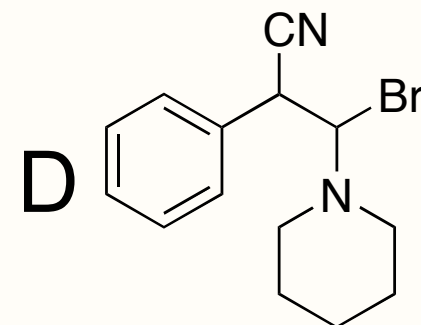
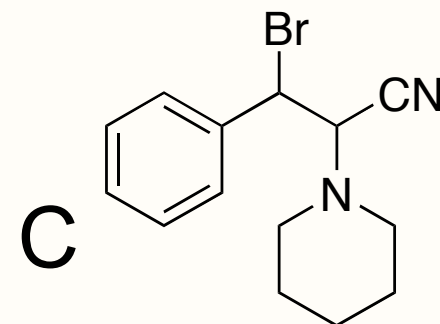
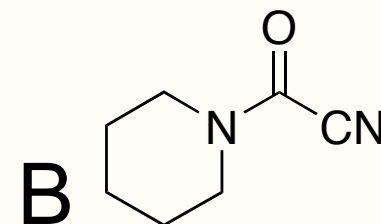
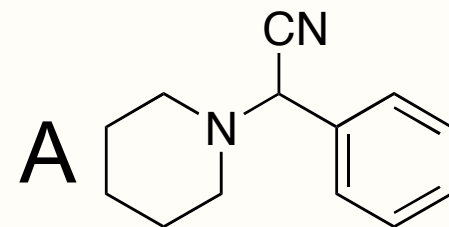


Self Test Question

Predict the product.

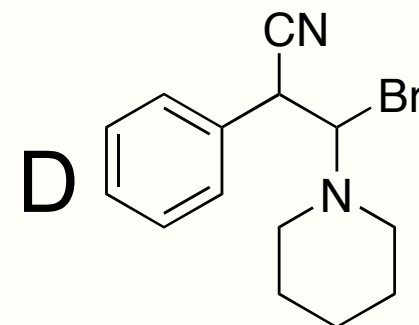
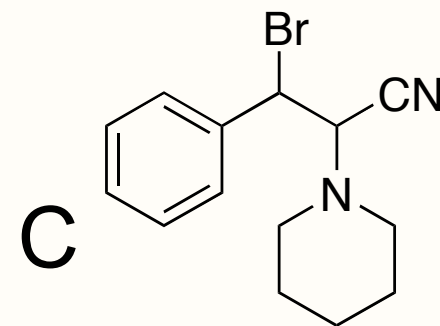
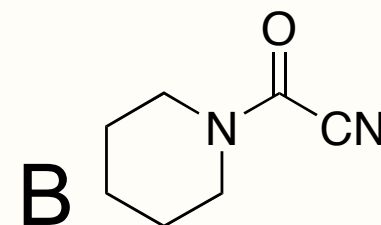
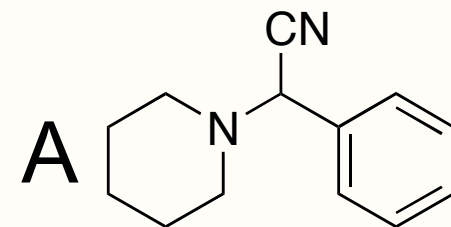
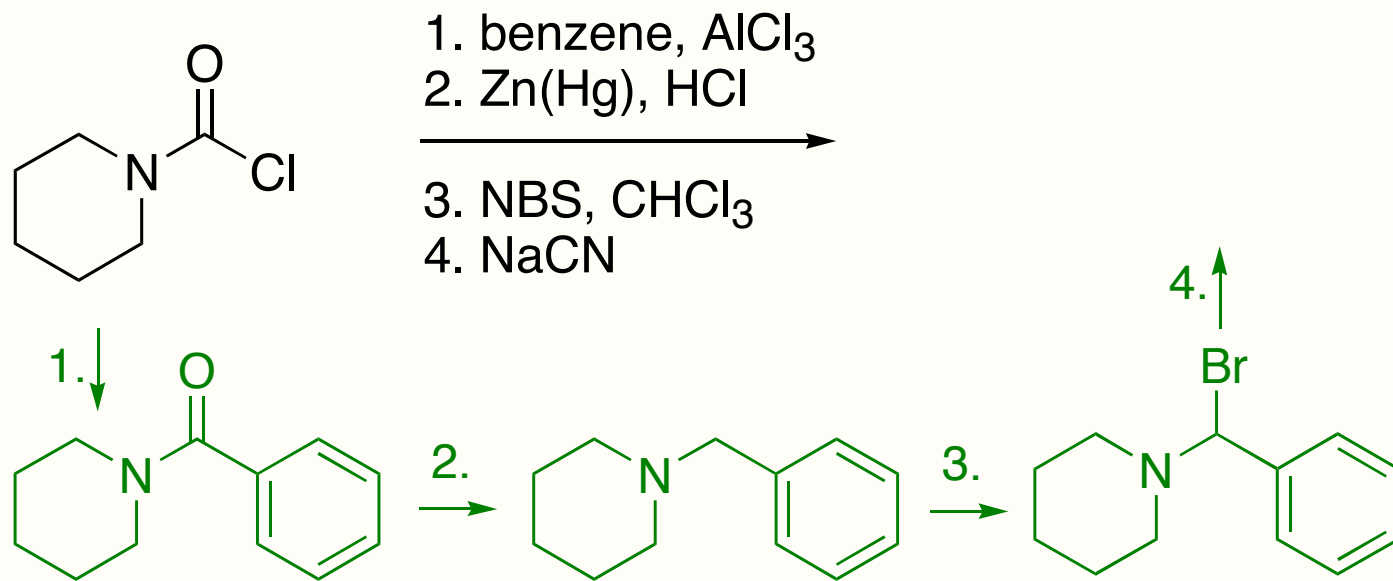


1. benzene, AlCl_3
 2. Zn(Hg) , HCl
-
3. NBS, CHCl_3
 4. NaCN



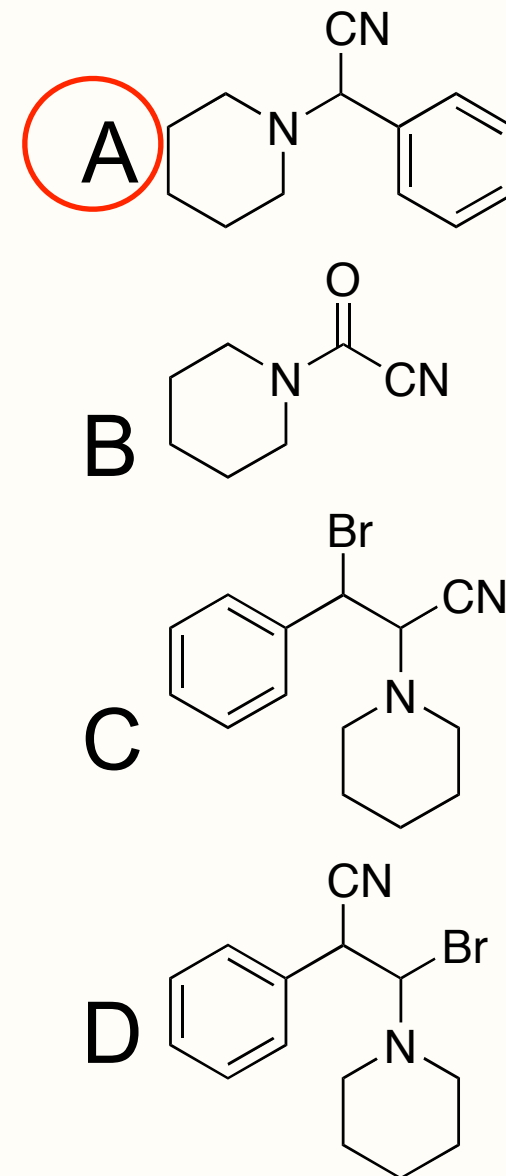
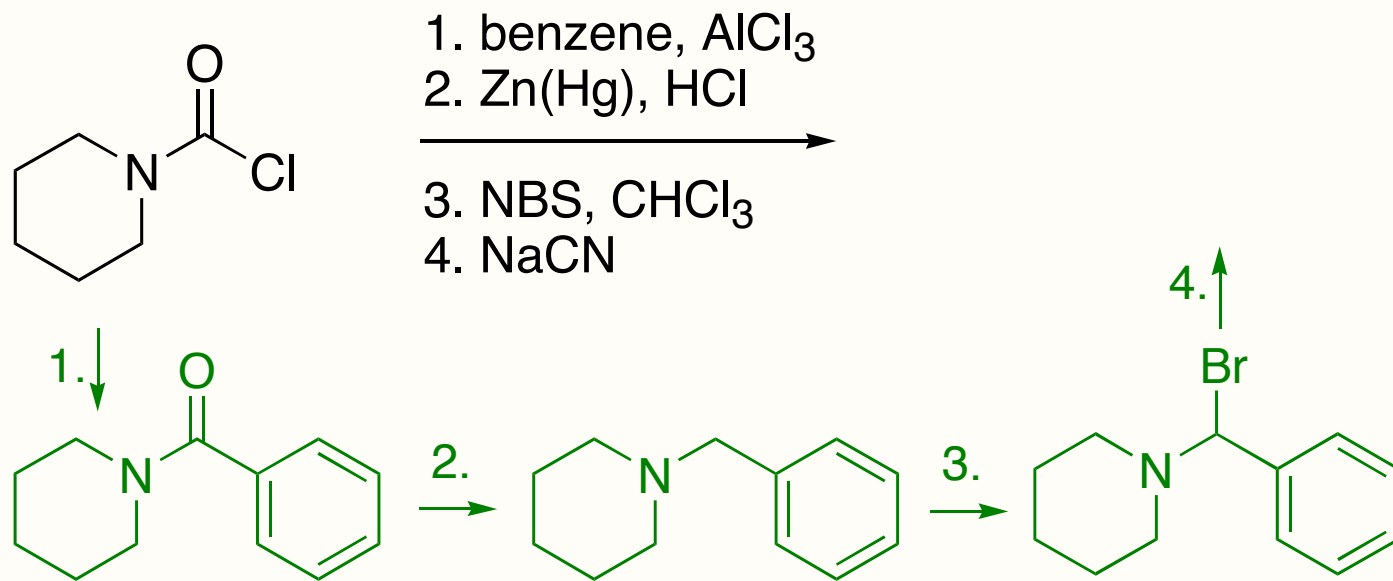
Self Test Question

Predict the product.



Self Test Question

Predict the product.



Next Lecture...

Chapter 12: Sections 12.9-12.13

Quiz Next Week. . .

Synthesis Problem

Chapters 11 & 12