

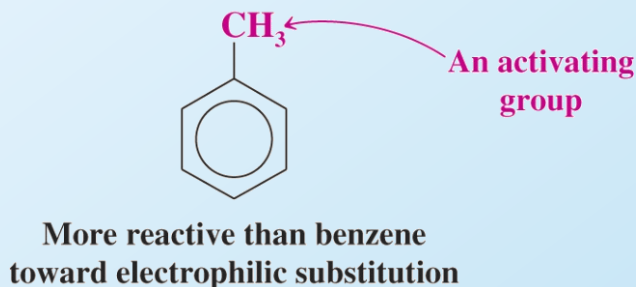
Electrophilic Reactions on Aromatic Compounds Di-and Polysubstitution

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Effect of Substituents

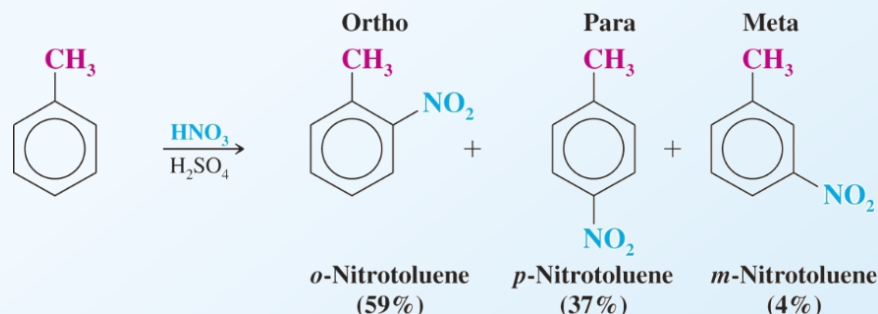
The nature of groups already on an aromatic ring affect both the reactivity and orientation of future substitution.

Activating Groups	Deactivating groups
Make benzene more electron rich; Making benzene more nucleophilic; Reaction is faster	Make benzene less electron rich; Making benzene less nucleophilic; Reaction is slower
Ortho para directors	Meta directors
Electron donating groups already present on the benzene ring	Electron withdrawing groups already present on the benzene ring

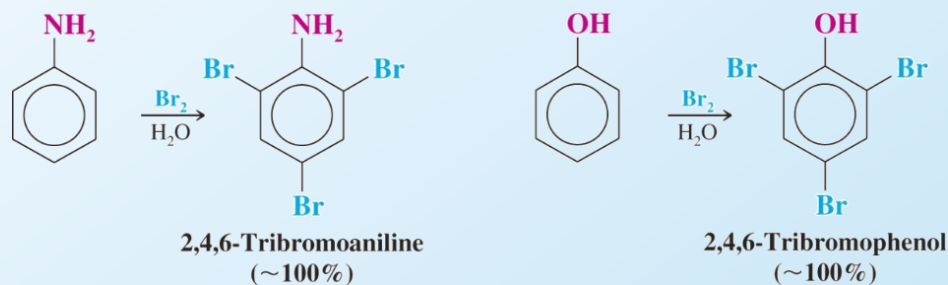


Ortho-para Directors (Activating Groups)

- The methyl group of toluene is an ortho-para director



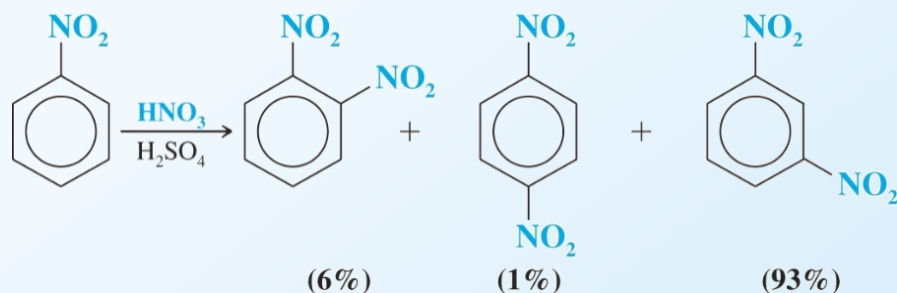
- Amino and hydroxyl groups are also activating and ortho-para directors
 - These groups are so activating that catalysts are often not necessary



- Alkyl groups and heteroatoms with one or more unshared electron pairs directly bonded to the aromatic ring will be ortho-para directors

Meta Directors (Deactivating Groups)

Strong electron-withdrawing groups such as nitro, carboxyl, and sulfonate are deactivators and meta directors



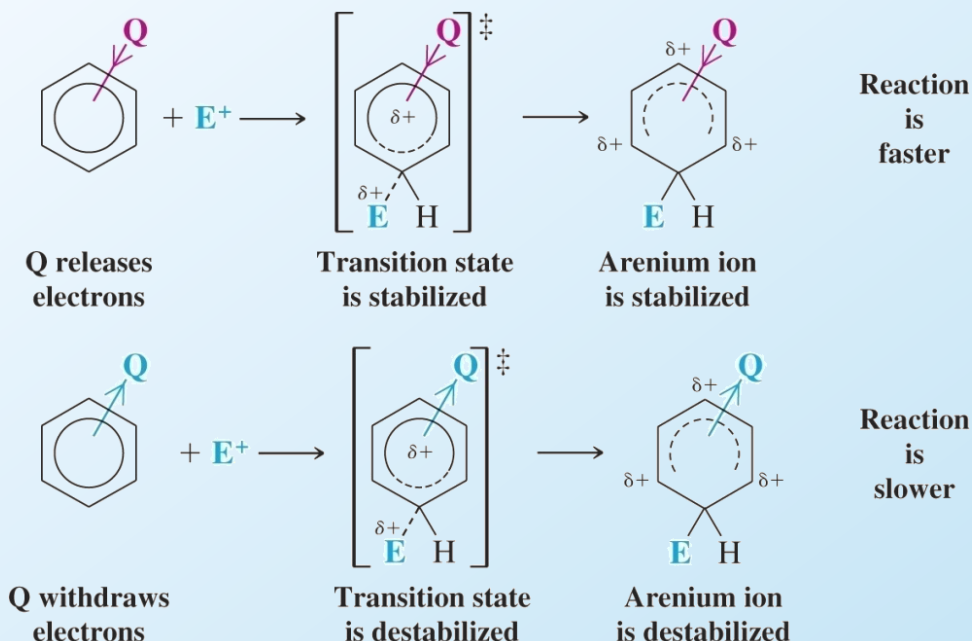
Halo Substitutents: Deactivating Ortho-Para Directors

- Chloro and bromo groups are weakly deactivating but are also ortho, para directors so the ortho and para products are major:

Reaction	Ortho Product (%)	Para Product (%)	Total Ortho and Para (%)	Meta Product (%)
Chlorination	39	55	94	6
Bromination	11	87	98	2
Nitration	30	70	100	
Sulfonation		100	100	

Theory of Substituent Effects on Electrophilic Substitution

- Reactivity: The Effect of Electron-Releasing and Electron-Withdrawing Groups
 - Electron-releasing groups activate the ring toward further reaction
 - Electron-withdrawing groups deactivate the ring toward further reaction.

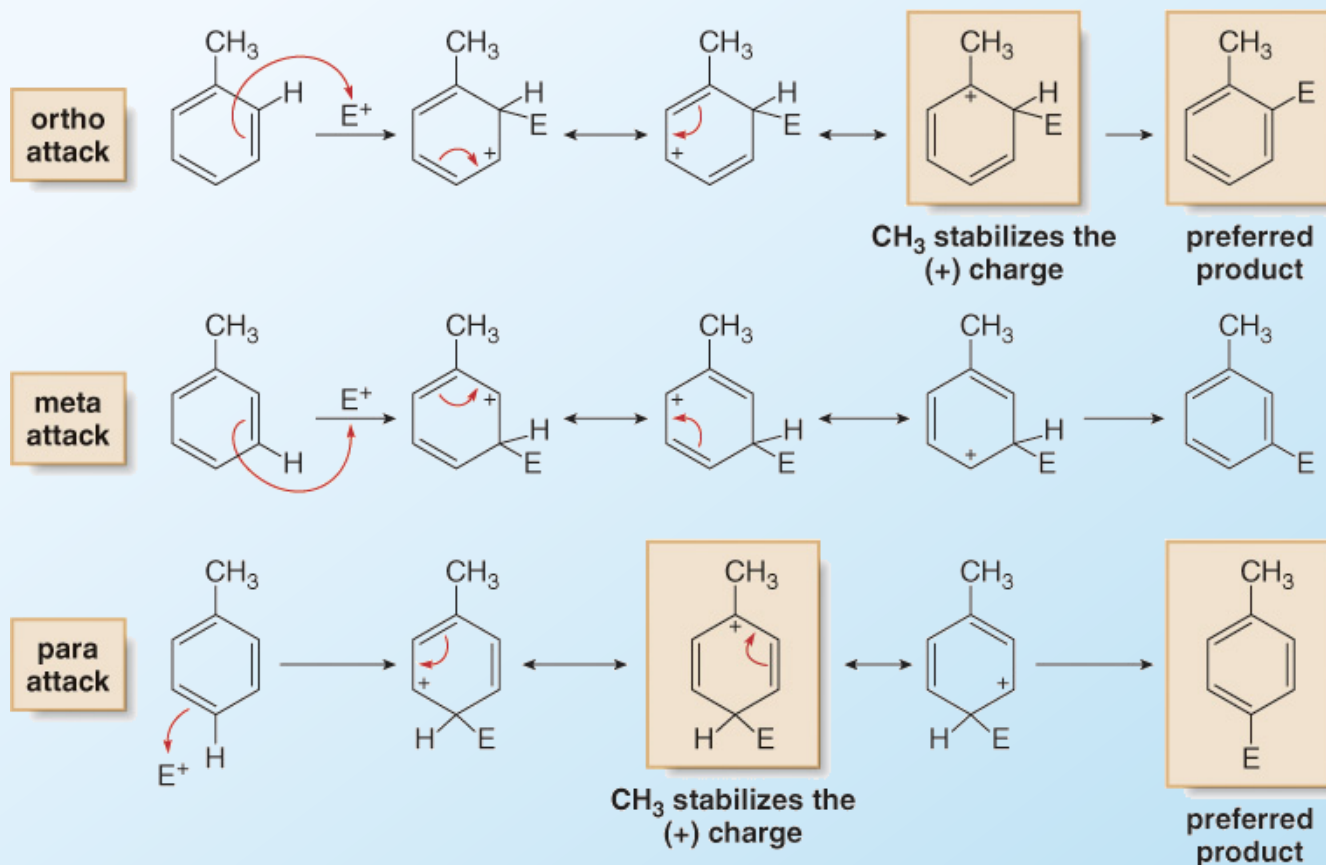


Classification of Groups

Ortho–Para Directors	Meta Directors
Strongly Activating $-\ddot{\text{N}}\text{H}_2, -\ddot{\text{N}}\text{HR}, -\ddot{\text{N}}\text{R}_2$ $-\ddot{\text{O}}\text{H}, -\ddot{\text{O}}:^-$	Moderately Deactivating $-\text{C}\equiv\text{N}$ $-\text{SO}_3\text{H}$ $-\text{CO}_2\text{H}, -\text{CO}_2\text{R}$ $-\text{CHO}, -\text{COR}$
Moderately Activating $-\ddot{\text{N}}\text{HCOCH}_3, -\ddot{\text{N}}\text{HCOR}$ $-\ddot{\text{O}}\text{CH}_3, -\ddot{\text{O}}\text{R}$	Strongly Deactivating $-\text{NO}_2$ $-\text{NR}_3^+$ $-\text{CF}_3, -\text{CCl}_3$
Weakly Activating $-\text{CH}_3, -\text{C}_2\text{H}_5, -\text{R}$ $-\text{C}_6\text{H}_5$	
Weakly Deactivating $-\ddot{\text{F}}:, -\ddot{\text{Cl}}:, -\ddot{\text{Br}}:, -\ddot{\text{I}}:$	

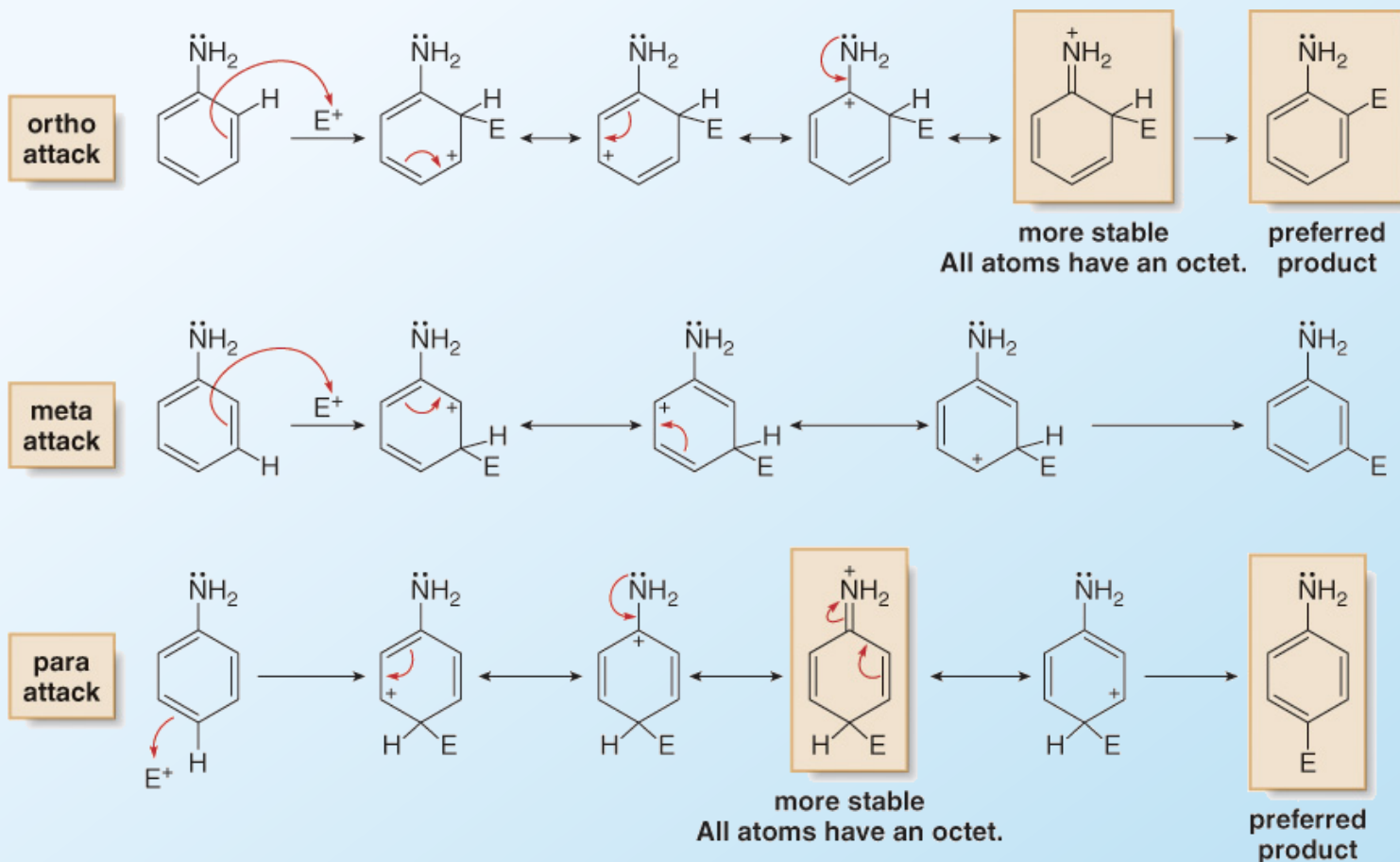
Orientation Effect – Activating Group

A CH_3 group directs electrophilic attack ortho and para to itself because an electron-donating inductive effect stabilizes the carbocation intermediate.



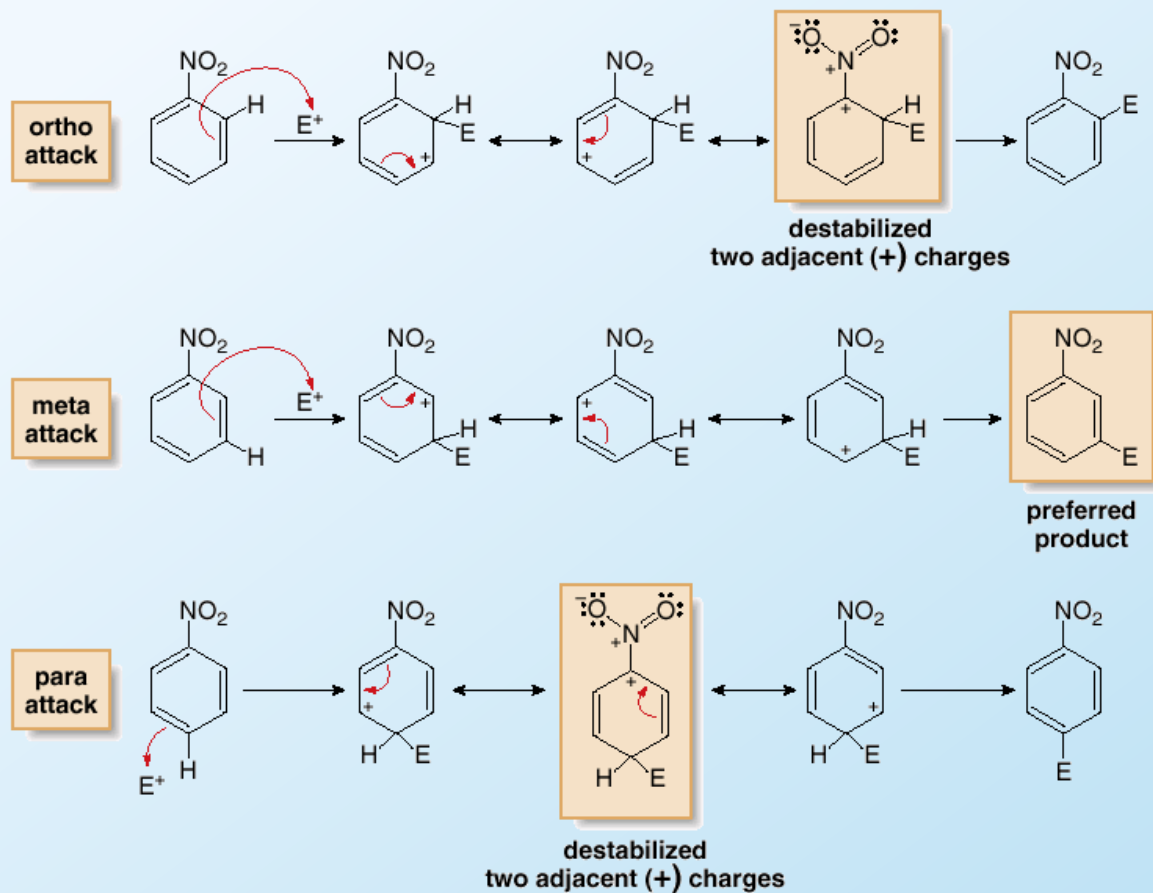
Orientation Effect – Activating Group, Contd..

An NH_2 group directs electrophilic attack ortho and para to itself because the carbocation intermediate has additional resonance stabilization.



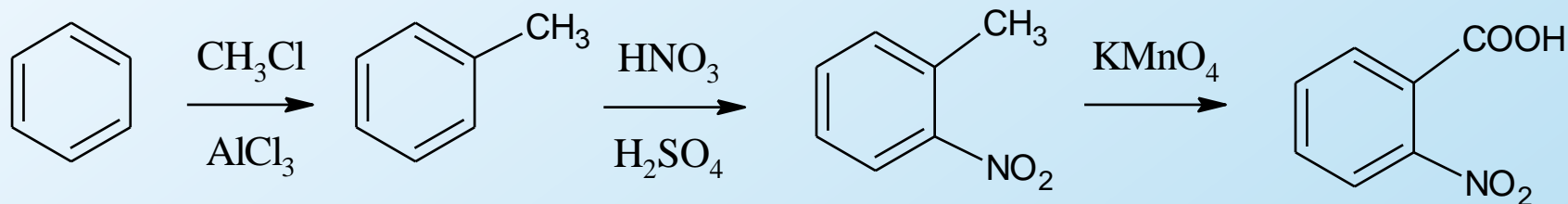
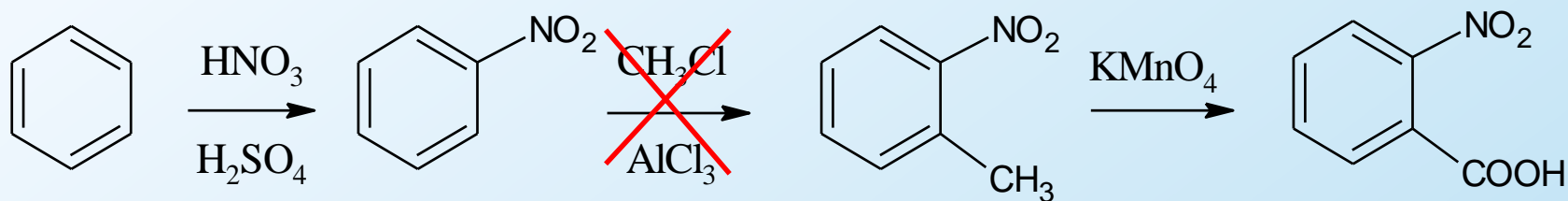
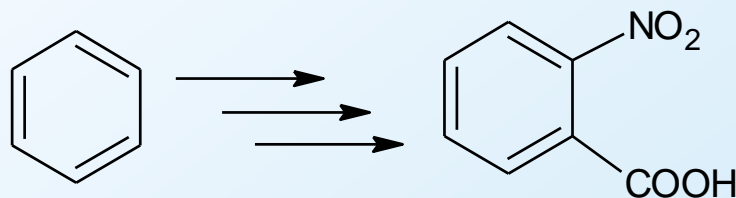
Orientation Effect – Deactivating Group

With the NO_2 group (and all meta directors) meta attack occurs because attack at the ortho and para position gives a destabilized carbocation intermediate.



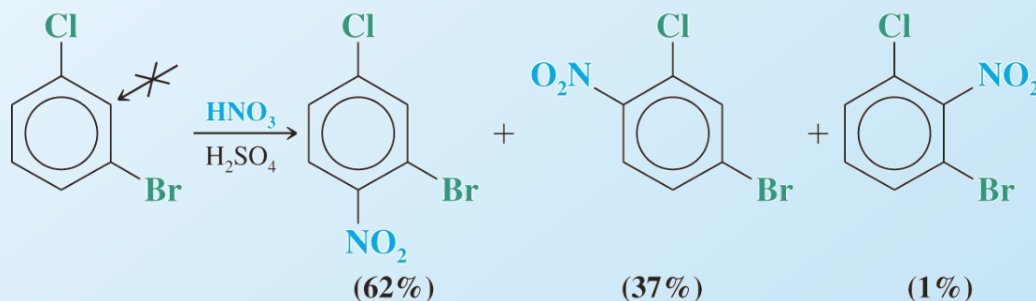
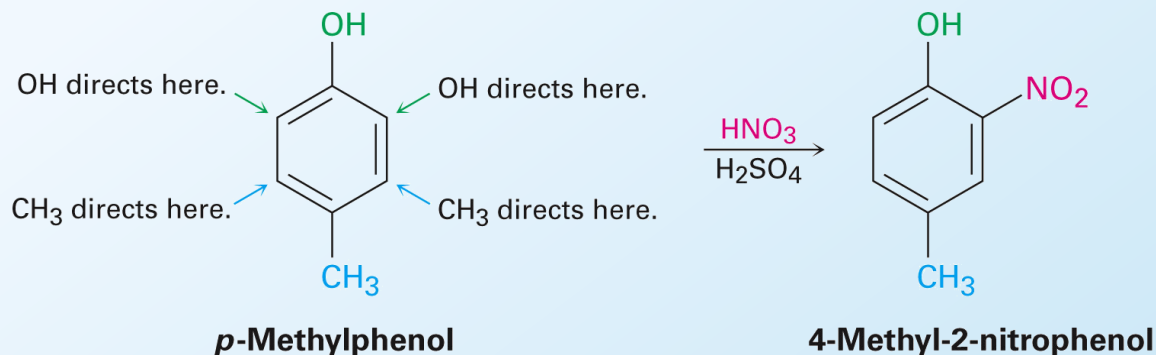
Synthetic Applications

- When designing a synthesis of substituted benzenes, the order in which the substituents are introduced is crucial
- Example: Synthesize ortho-nitrobenzoic acid from benzene



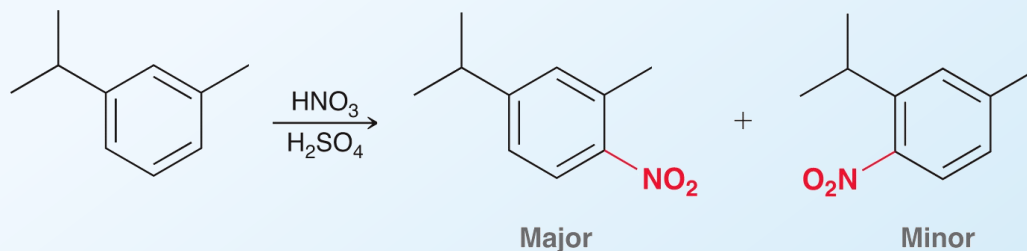
Trisubstitution on Benzene Ring

- When two substituents are present on the ring initially, the more powerful activating group generally determines the orientation of subsequent substitution
 - Ortho-para directors determine orientation over meta directors
 - Substitution does not occur between meta substituents due to steric hindrance

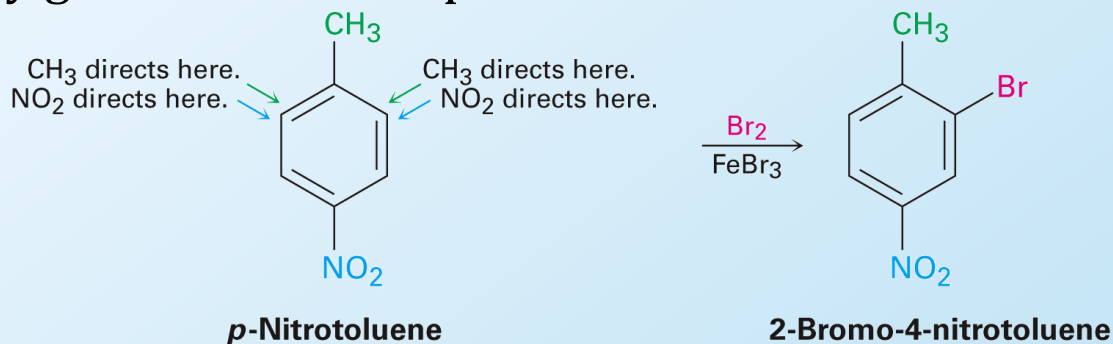


Trisubstitution on Benzene contd...

- If both groups are the same directors; then follow the steric hinderance rule.



- If the directing effects of two groups oppose each other, the more powerful activating group decides the principal outcome
- Usually gives mixtures of products



Key Concepts

- Activating and deactivating groups
- Resonance stabilization of intermediate
- Trisubstitutions