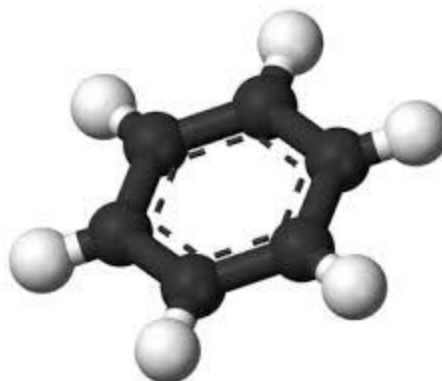


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# Aromatic – Miscellaneous Reactions

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## **Recommended Textbook:**

Chapter 17 in *Organic Chemistry*, 8<sup>th</sup> Edition, L. G. Wade, Jr., **2010**,  
Prentice Hall (Pearson Education)

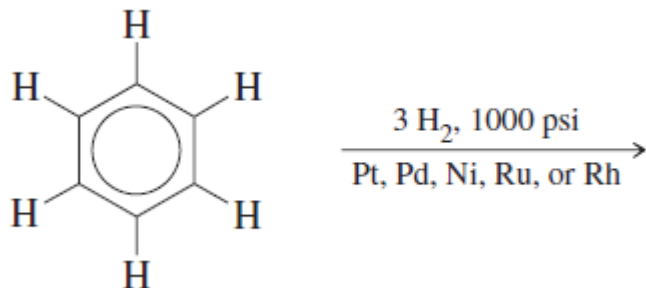
# Reactions of Aromatic Compounds

- **Electrophilic Aromatic Substitution**
  - Halogenation (usually Br<sub>2</sub>)
  - Nitration
  - Sulfonation
  - Friedel-Craft Alkylation/Acylation
- **Nucleophilic Aromatic Substitution**
- **Miscellaneous**
  - Reduction of Aromatic Rings
    - Catalytic hydrogenation
    - Birch reduction
  - Reaction at the side chain
    - Permanganate oxidation
    - Side-chain halogenation & Substitution

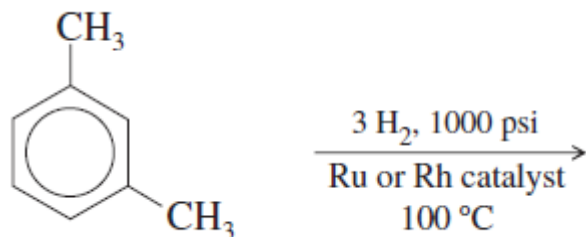
# Reduction of Aromatic Rings

## Catalytic hydrogenation

- Takes place at **elevated temperatures and pressures**, often catalyzed by **ruthenium or rhodium-based catalysts**.



- Substituted benzenes react to give substituted cyclohexanes;
- Disubstituted benzenes usually give mixtures of cis and trans isomers.

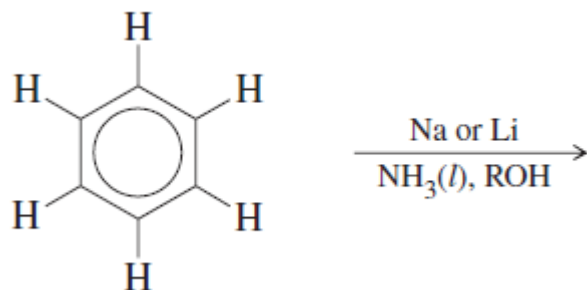


- The reduction cannot be stopped at an intermediate stage because alkenes are reduced faster than benzene.

# Reduction of Aromatic Rings

## Birch reduction

- Benzene derivatives are reduced to **nonconjugated cyclohexa-1,4-dienes** by treatment with **sodium or lithium** in a mixture of **liquid ammonia** and an **alcohol**.



- The mechanism of the Birch reduction is similar to the sodium/liquid ammonia **reduction of alkynes to *trans*-alkenes**

# Reduction of Aromatic Rings

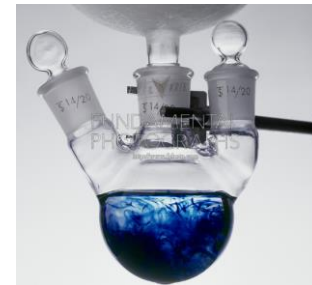
## Birch reduction

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- **Mechanism**

**Preceding step:** Formation of solvated electrons in the ammonia solution.

**Steps 1 and 2:** Addition of an electron, followed by a proton, forms a radical.



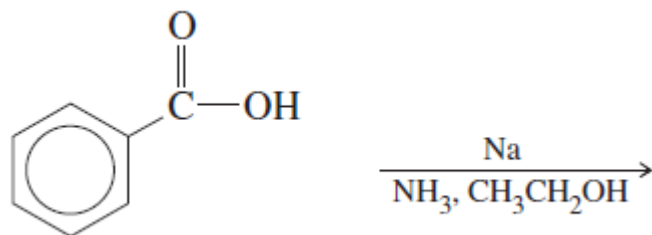
**Steps 3 and 4:** Addition of a second electron, followed by a proton, gives the product.

# Reduction of Aromatic Rings

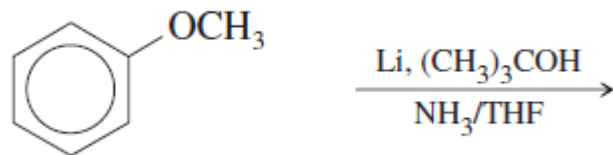
## Birch reduction

- **Selectivity**

**Electron-withdrawing** substituents stabilize the carbanions:



**Electron-donating** substituents destabilize them:



**Rate: EWG > EDG** : Lithium is often used with these deactivated systems

# Reduction of Aromatic Rings

- **Example**

Predict the major products of the following reactions.

(a) benzamide ( $\text{PhCONH}_2$ ) + Na (liquid  $\text{NH}_3$ ,  $\text{CH}_3\text{CH}_2\text{OH}$ )

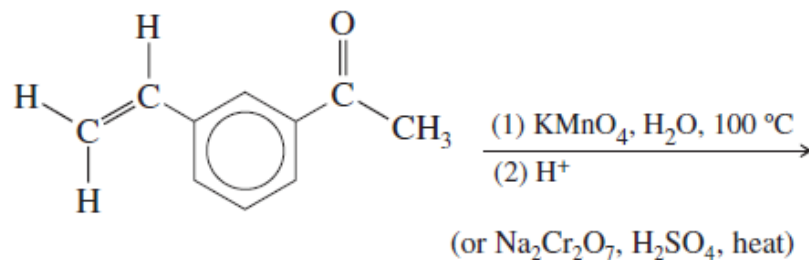
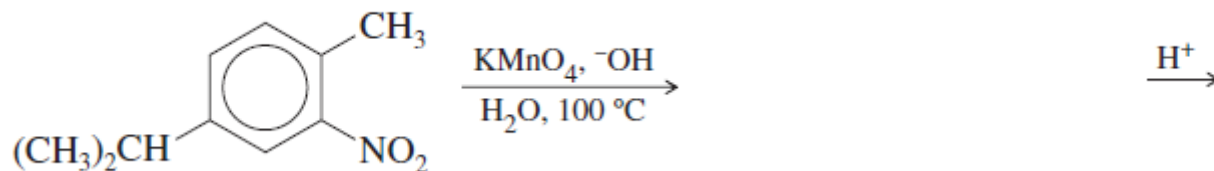
(b) *o*-xylene +  $\text{H}_2$  (1000 psi, 100 °C, Rh catalyst)

(c) *p*-xylene + Na (liquid  $\text{NH}_3$ ,  $\text{CH}_3\text{CH}_2\text{OH}$ )

# Reaction at the side chain

## Permanganate oxidation

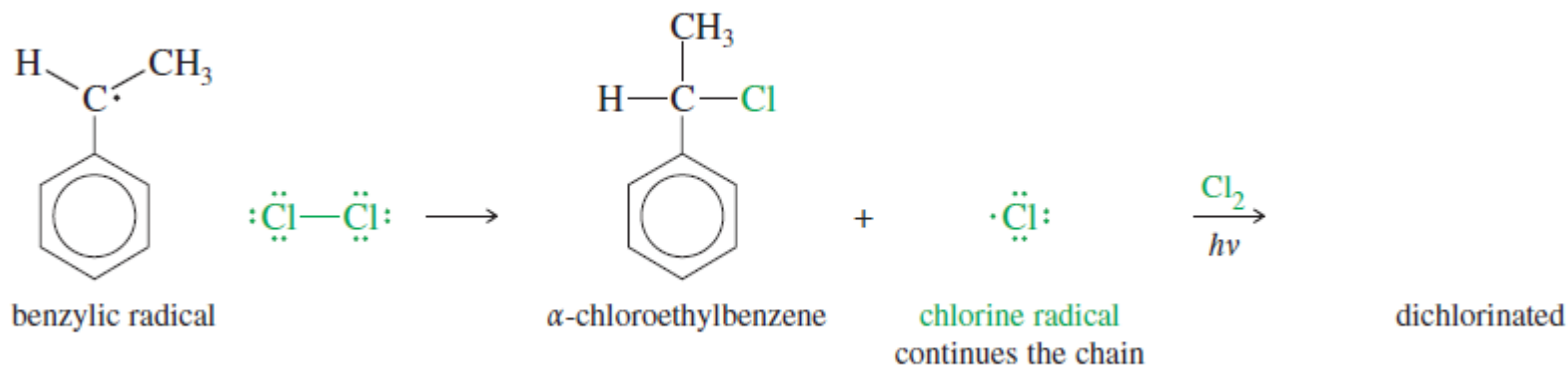
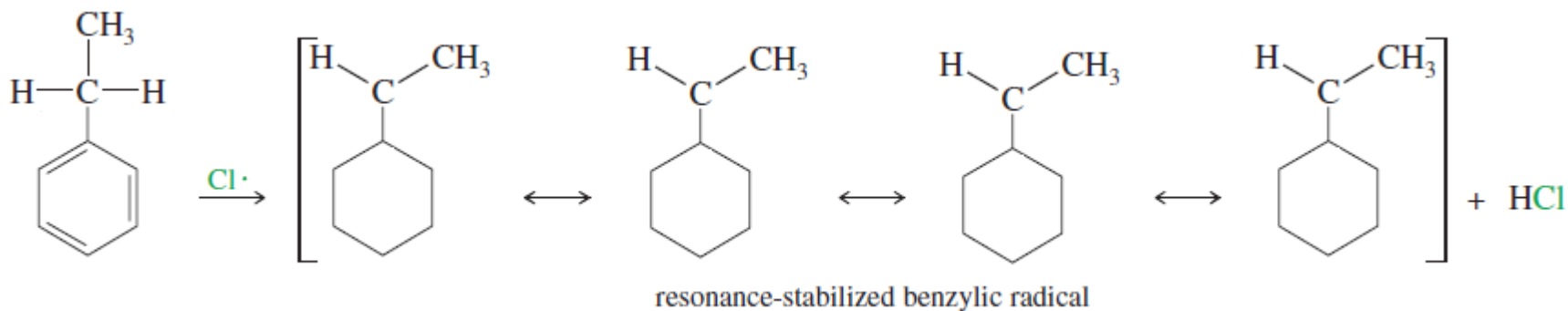
- An aromatic ring imparts **extra stability** to the nearest carbon atom of its side chains.
- The aromatic ring and one carbon atom of a side chain can survive a vigorous **permanganate oxidation**. The product is a **carboxylate salt of benzoic acid**. (**Hot chromic acid** can also be used for this oxidation.)



- This oxidation is occasionally useful for making benzoic acid derivatives, as long as any other functional groups are **resistant to oxidation**. (-NO<sub>2</sub>, -halogen, -COOH, -SO<sub>3</sub>H)



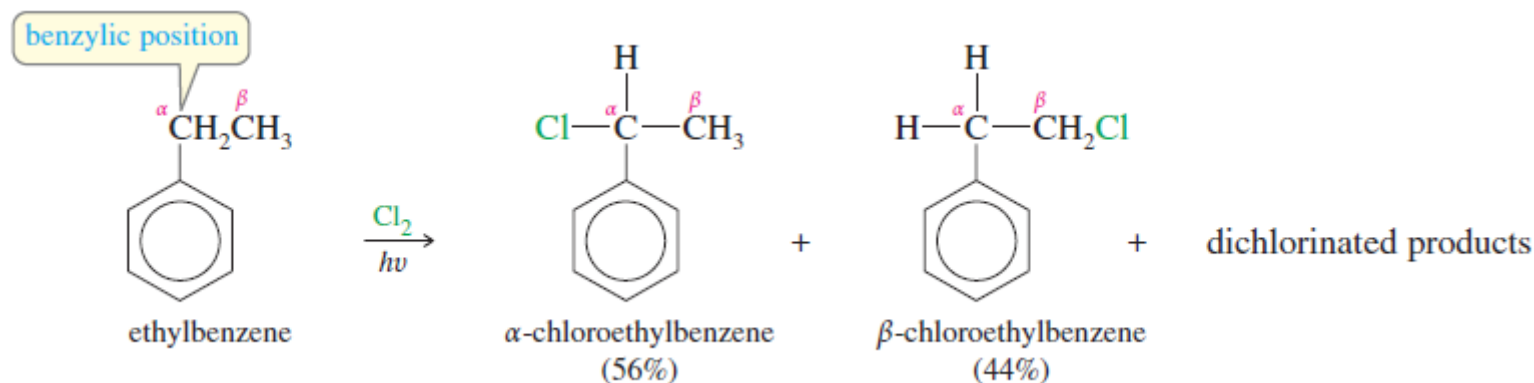
- Alkylbenzenes undergo **free-radical halogenation** much more easily than alkanes
- abstraction of a hydrogen atom at a **benzylic** position gives a resonance-stabilized **benzylic radical**



# Reaction at the side chain

## Halogenation & Substitution

- Although chlorination shows a preference for **alpha** substitution, the chlorine radical is **too reactive** to give entirely benzylic substitution. **Mixtures of isomers** are often produced.



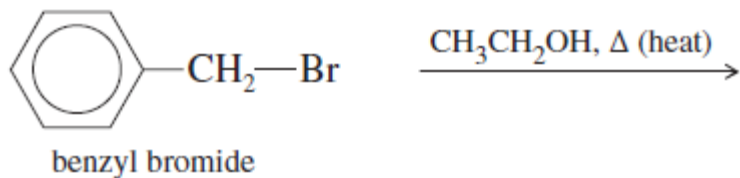
- Bromine radicals** are not as reactive as chlorine radicals, so bromination is more selective than chlorination. Bromine reacts exclusively at the **benzylic position**.



## Nucleophilic Substitution at the Benzylic Position

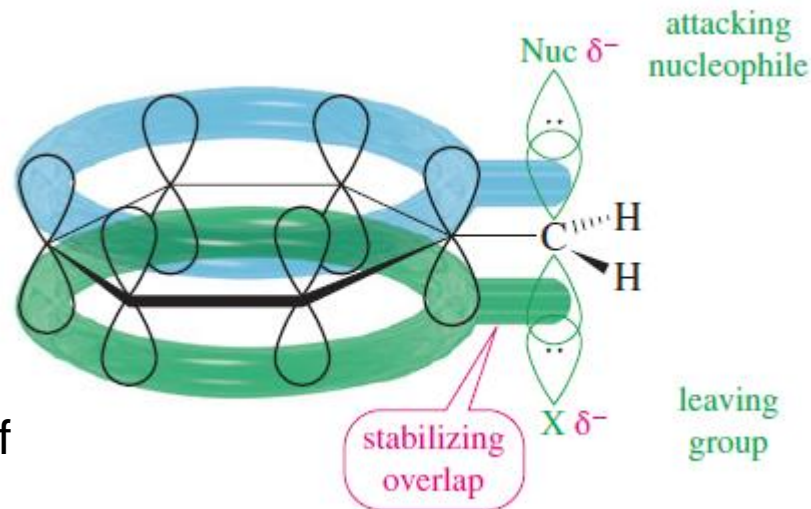
- Benzylic halides are **more reactive** in both  $S_N1$  and  $S_N2$  reactions

$S_N1$ : requires ionization of the halide to give a **carbocation**. In the case of a benzylic halide, the carbocation is **resonance-stabilized**.



**S<sub>N</sub>2**: benzylic halides are about **100 times more reactive** than primary alkyl halides

the p orbital partially bonds with the nucleophile and the leaving group also **overlaps** with the pi electrons of the ring



This stabilizing conjugation lowers the energy of the transition state, increasing the reaction rate.

