Oxidation of Alkyl Side-Chains

The benzylic hydrogens of alkyl substituents on a benzene ring are activated toward free radical attack, as noted earlier. Furthermore, $S_N1$, $S_N2$ and E1 reactions of benzylic halides, show enhanced reactivity, due to the adjacent aromatic ring. The possibility that these observations reflect a general benzylic activation is supported by the susceptibility of alkyl side-chains to oxidative degradation, as shown in the following examples (the oxidized side chain is colored). Such oxidations are normally effected by hot acidic permanganate solutions, but for large scale industrial operations catalyzed air-oxidations are preferred. Interestingly, if the benzylic position is completely substituted this oxidative degradation does not occur (second equation, the substituted benzylic carbon is colored blue).

\[
\text{C}_6\text{H}_5-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3 + \text{KMnO}_4 + \text{H}_3\text{O}^{(+)} \text{ & heat} \rightarrow \text{C}_6\text{H}_5-\text{CO}_2\text{H} + \text{CO}_2
\]

\[
p-(\text{CH}_3)_3\text{C}-\text{C}_6\text{H}_4-\text{CH}_3 + \text{KMnO}_4 + \text{H}_3\text{O}^{(+)} \text{ & heat} \rightarrow p-(\text{CH}_3)_3\text{C}-\text{C}_6\text{H}_4-\text{CO}_2\text{H}
\]

These equations are not balanced. The permanganate oxidant is reduced, usually to Mn(IV) or Mn(II). Two other examples of this reaction are given below, and illustrate its usefulness in preparing substituted benzoic acids.

Reduction of Nitro Groups and Aryl Ketones

Electrophilic nitration and Friedel-Crafts acylation reactions introduce deactivating, meta-directing substituents on an aromatic ring. The attached atoms are in a high oxidation state, and their reduction converts these electron withdrawing functions into electron donating amino and alkyl groups. Reduction is easily achieved either by catalytic hydrogenation (H2 + catalyst), or with reducing metals in acid. Examples of these reductions are shown here, equation 6 demonstrating the simultaneous reduction of both functions. Note that the butylbenzene product in equation 4 cannot be generated by direct Friedel-Crafts alkylation due to carbocation rearrangement. The zinc used in ketone reductions, such as 5, is usually activated by alloying with mercury (a process known as amalgamation).
Several alternative methods for reducing nitro groups to amines are known. These include zinc or tin in dilute mineral acid, and sodium sulfide in ammonium hydroxide solution. The procedures described above are sufficient for most cases.

### Conversion of Halogens to Organometallic Reagents

The reaction of alkyl and aryl halides with reactive metals (usually Li & Mg) to give nucleophilic reagents has been noted. This provides a powerful tool for the conversion of chloro, bromo or iodo substituents into a variety of other groups. Many reactions of these aryl lithium and Grignard reagents will be discussed in later sections, and the following equations provide typical examples of carboxylation, protonation and Gilman coupling. Metal halogen exchange reactions take place at low temperature, and may be used to introduce iodine at designated locations. An example of this method is displayed below. In this example care must be taken to maintain a low temperature, because elimination to an aryne intermediate takes place on warming.

![Equations](https://via.placeholder.com/150)

### Hydrolysis of Sulfonic Acids

The potential reversibility of the aromatic sulfonation reaction was noted earlier. The following equation illustrates how this characteristic of the sulfonic acids may be used to prepare the 3-bromo derivative of ortho-xylene. Direct bromination would give the 4-bromo derivative.

![Equation](https://via.placeholder.com/150)

### Contributors