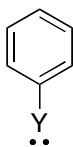


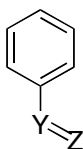
Electrophilic Substitution of Substituted Benzenes

	<u>Resonance Effect</u>	<u>Inductive Effect</u>
e^- donating	C=C, π system Strong Activate <i>ortho</i> and <i>para</i> directing	Single bonds, σ Weak Activate <i>ortho</i> and <i>para</i> directing
e^- withdrawing	Deactivate (less reactive) <i>meta</i> directing	Deactivate (less reactive) <i>meta</i> directing

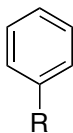
Aromatic compounds with a heteroatom attached to it with a lone pair of electrons is considered a resonance donating system and will direct the reaction to the *ortho* or *para* positions.



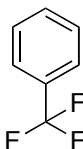
Aromatic compounds with a conjugated double bond conjugated to the aromatic ring are generally resonance withdrawing (especially if Z is electronegative) and will direct aromatic substitution to the *meta* position.



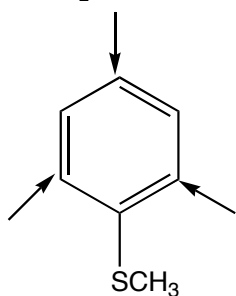
Aromatic compounds with an alkyl chain are considered inductively donating and will direct substitution to the *ortho* or *para* positions.



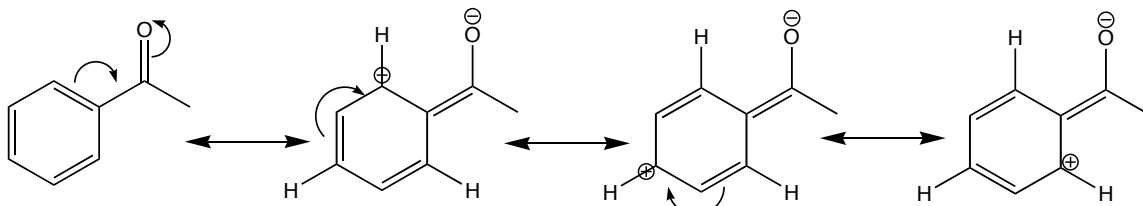
Aromatic compounds that have an electron withdrawing group attached but that do not fall into the above categories (eg. CF_3) are inductively withdrawing and direct substitution to the *meta* position.



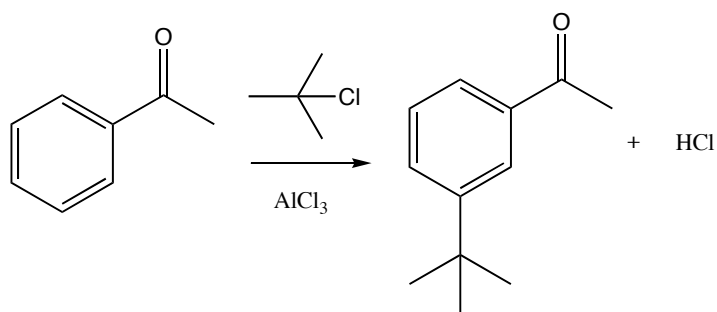
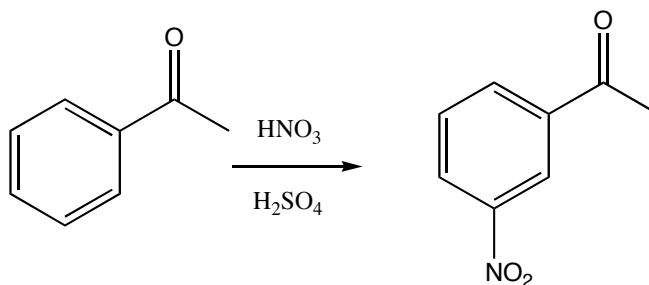
Examples



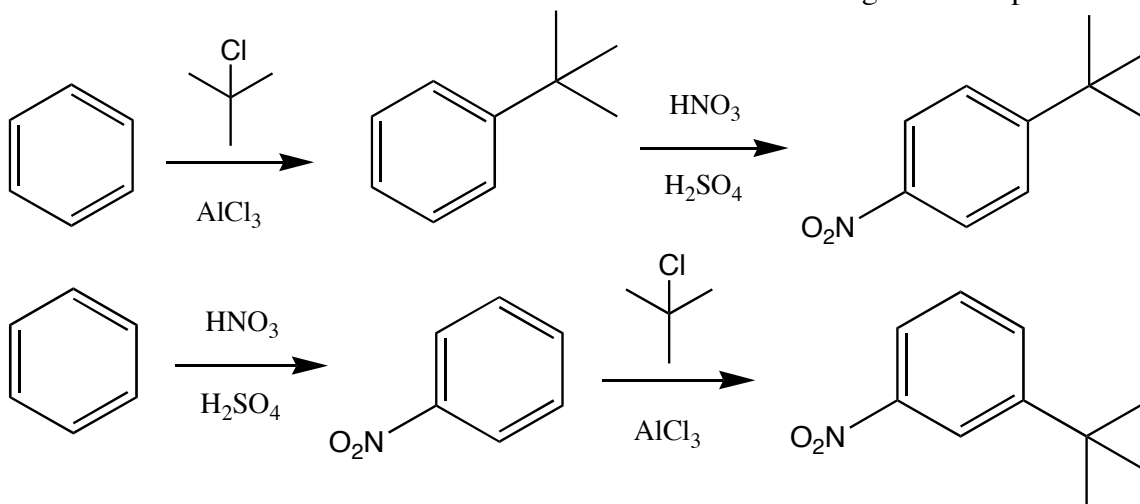
S is under O in the periodic table
It has two lone pairs, so is resonance donating
It is *ortho* and *para* directing



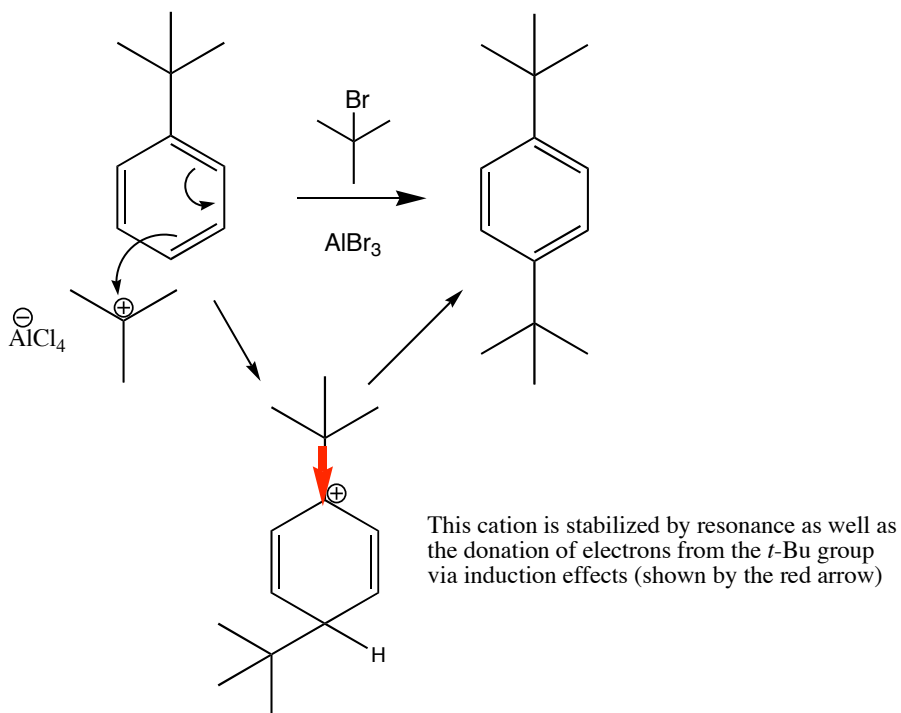
Acetophenone is *meta* directing. When the electrophile attacks it avoids the partial positive charges on the *ortho* and *para* positions.



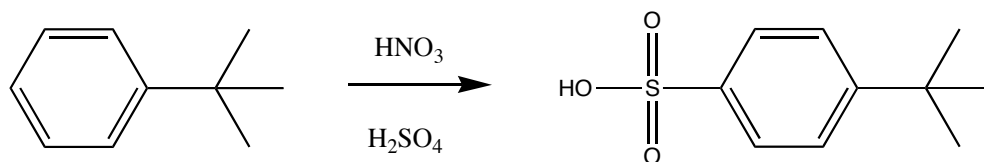
Notice how the order that reactions are done in affects the following two examples:



The final products of the above two series of reactions are structural (or constitutional) isomers.



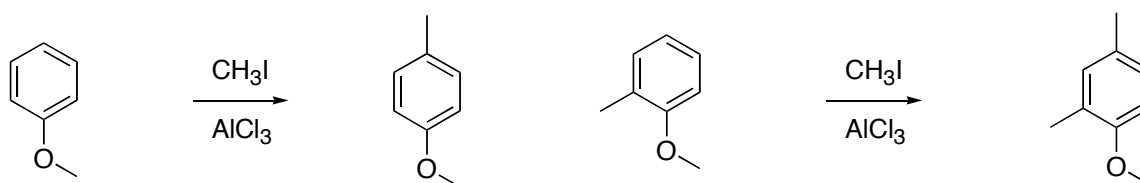
This reaction occurs at the *para* position instead of the *ortho* position due to sterics. The same is true of the next reaction:



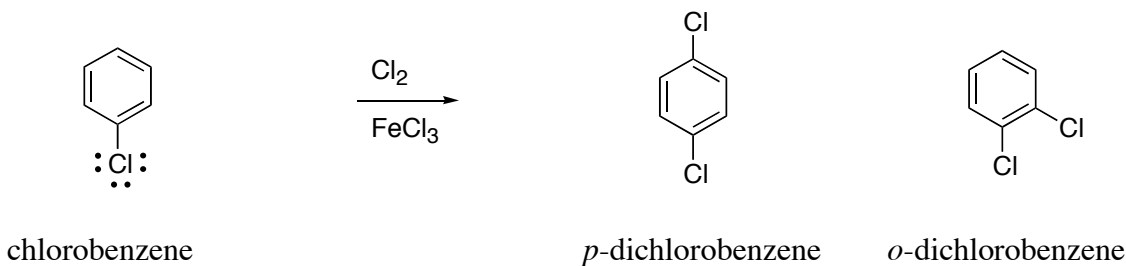
Additional Substitution

If there is more than one group on an aromatic ring, electrophilic aromatic substitution is controlled by the **strongest donating group**.

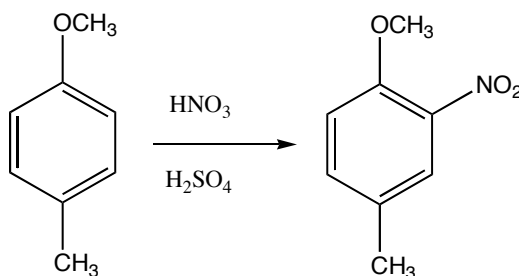
This is governed by the same resonance and inductive effects discussed before but it is necessary to consider the effects of the two groups. An example is the di-alkylation of methoxybenzene with methyl iodide by a Friedel-Crafts alkylation. Since the methoxy group is an electron donating group (resonance donator), it will direct the first alkylation to the *ortho* and *para* positions. The second alkylation is also directed to the *ortho* and *para* positions relative to the methoxy group because it is a stronger director (resonance donator) than the methyl group (inductive donator). The second alkylation will go *ortho* to the methoxy rather than *ortho* to the methyl. As demonstrated, the strongest donating group always determines the site of substitution.

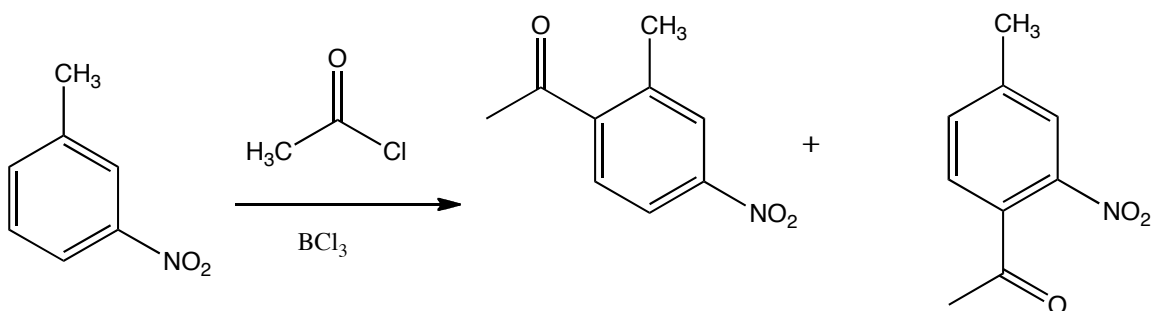


An interesting example is the chlorination of chlorobenzene. In this case, the inductive effects of the chlorine could suggest the substitution should go *meta*, but chlorine also displays a resonance effect which directs substitution to the *ortho* and *para* positions. In general, a resonance effect always is a stronger director than an inductive effect.

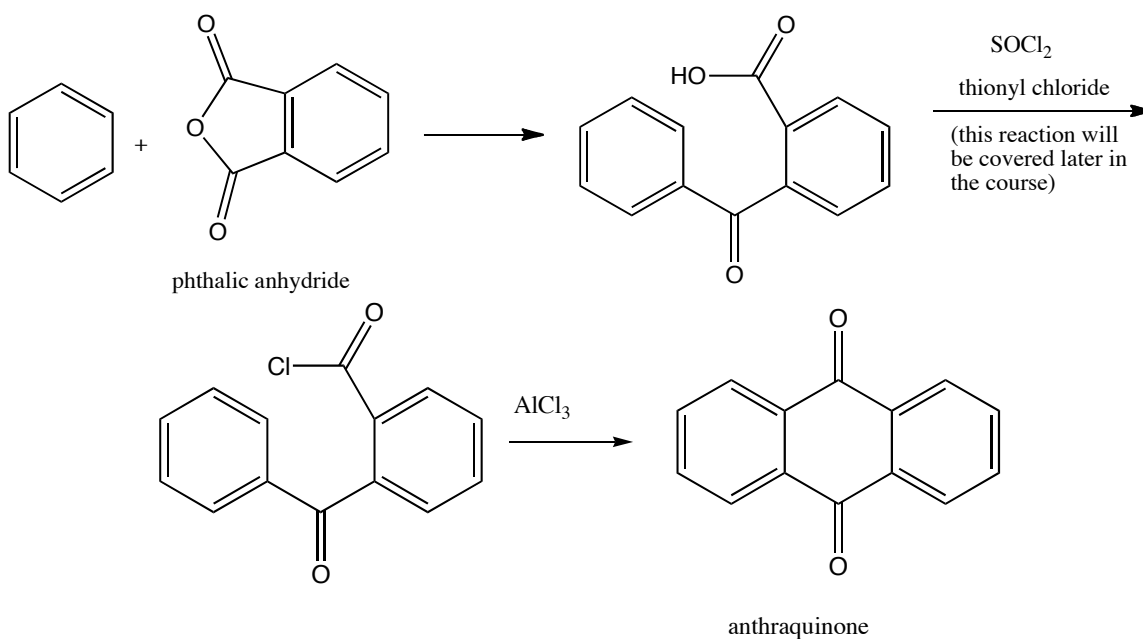


More examples:





In this case, the nitro group is an electron withdrawing group, so the methyl group is the strongest donating group and takes precedent over where the acetyl group will go. Note that the position that is *ortho* to both the methyl and nitro groups (between meta substituents) is too sterically hindered for the acetyl to form a bond with that carbon.



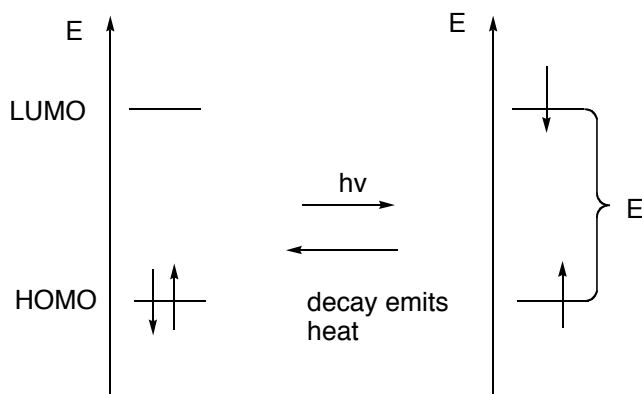
An unexpected example (“exception”) is the Friedel-Crafts acylation of benzene shown above. After the first two reactions, the substituent (a ketone) would normally direct the second acylation to the *meta* position as a resonance withdrawer. This does not occur as this would produce a very strained structure. In this example, the second acylation goes to the *ortho* position to relieve the strain to produce anthraquinone. 6-rings are also favoured

Fluorescence

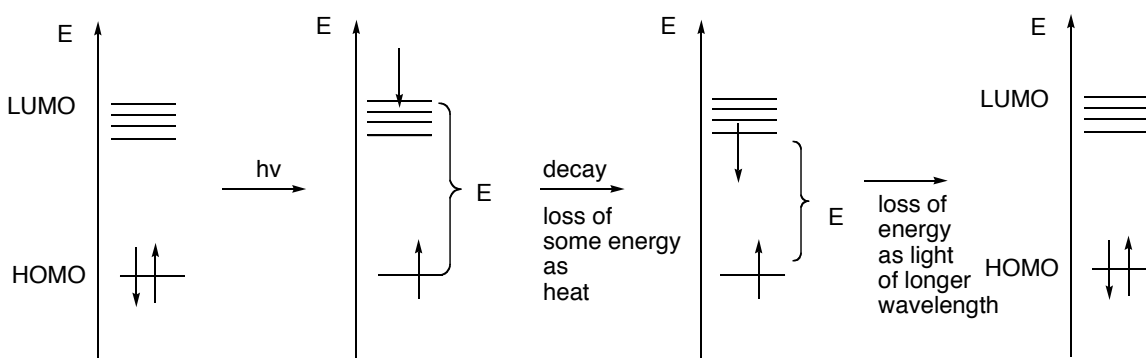
Fluorescence is the emission of electromagnetic energy from an excited state (obtained by irradiation, normally in the ultraviolet) as light (usually visible wavelengths).

Commonly, electromagnetic radiation (light) is absorbed if it matches the difference between the highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO). The promoted electron in the LUMO then decays back to the

HOMO with loss of the energy as heat (molecular motion, collision with other molecules).



However, if a conjugated molecule absorbs a high-energy photon into a higher vibrational state of the LUMO or a higher unoccupied MO and the electron energy decays to the lowest vibrational excited state of the LUMO (loss of energy as heat), the remaining energy to return to the ground state can be emitted as a lower-energy photon with a longer wavelength (visible).



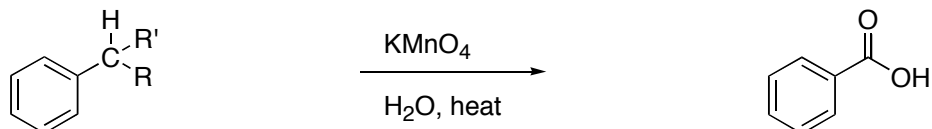
Ground State

There are many natural conjugated molecules that exhibit fluorescence, for example, green fluorescence protein (GFP). Phosphorescence also occurs for some natural compounds if the electrons become unpaired. Phosphorescence is slower than fluorescence and can be seen in novelty items such as 'glow in the dark' stars that can be stuck to the wall.

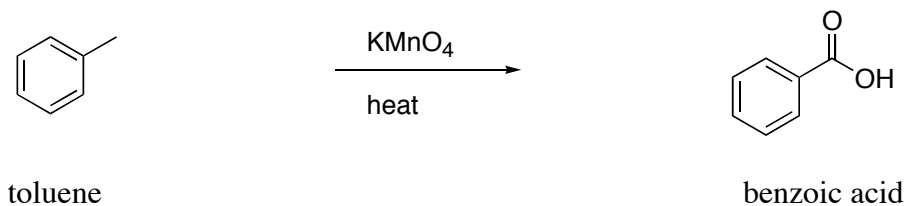
Reactions of Side Chains of Aromatic Compounds (3 types to be discussed)

Alkyl Side Chain Oxidation Reaction

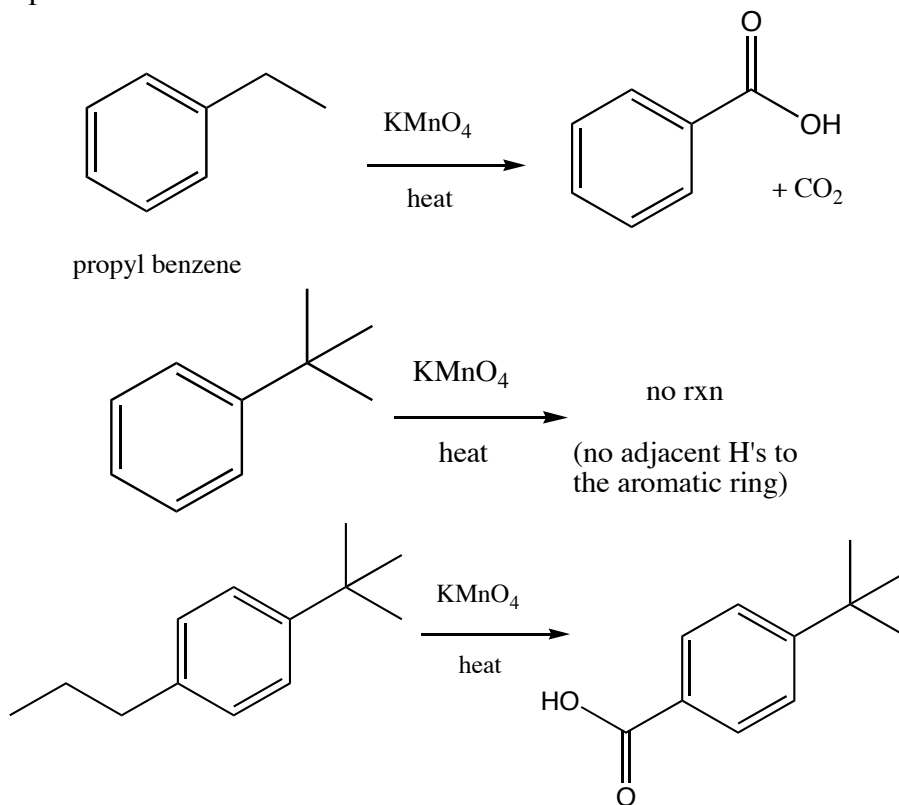
If the carbon directly attached to the aromatic ring has ≥ 1 hydrogen attached to it, it can be oxidized to the carboxylic acid with hot aqueous potassium permanganate (KMnO_4) as shown below. The mechanism is slightly complicated, and you're not expected to know it. Carbon dioxide is typically a product, although depending on the conditions various byproducts can occur.

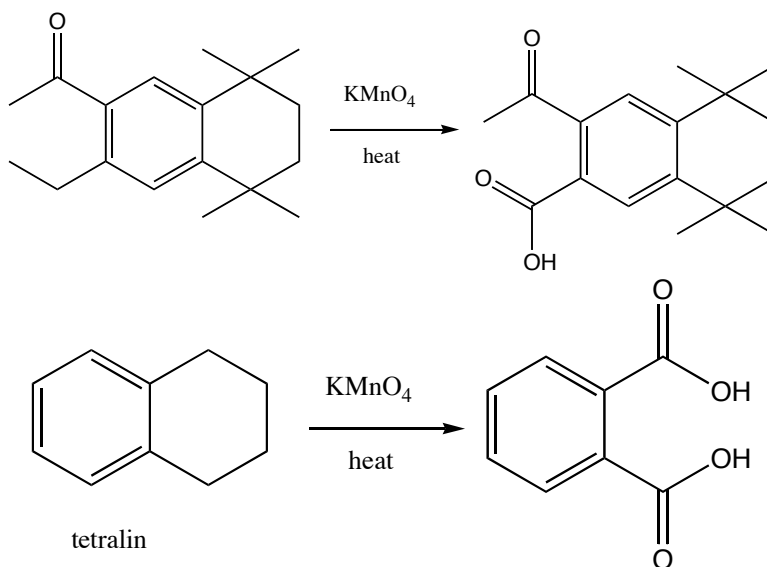


An example is the oxidation of toluene to benzoic acid.



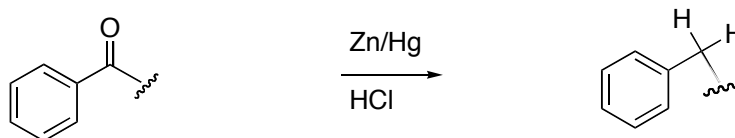
More examples:



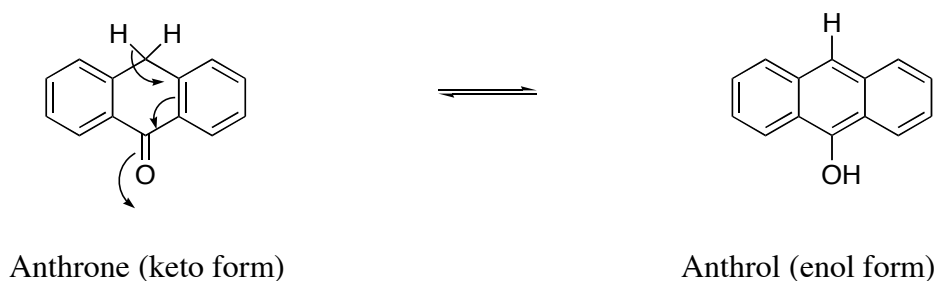


Clemmensen Side Chain Reduction Reaction

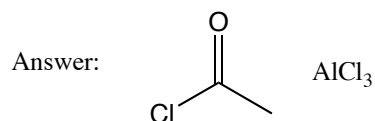
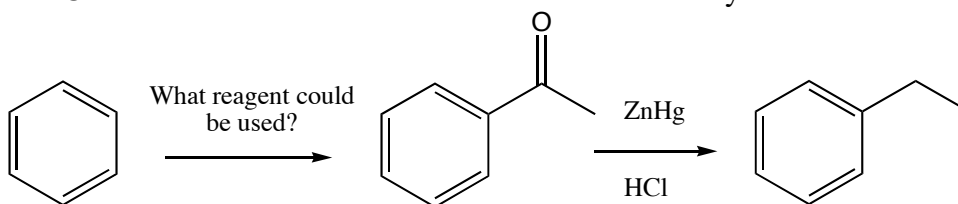
The Clemmensen reduction is an example of a reduction of a conjugated ketone to the alkyl chain using a zinc/mercury and an acid as shown below.



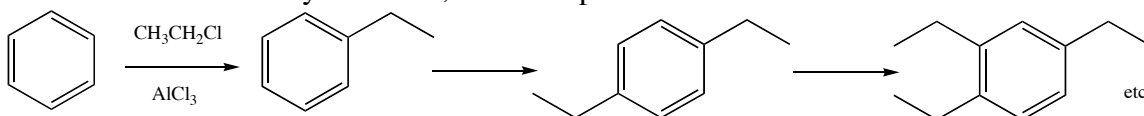
This reaction could in principle be used to reduce anthraquinone to anthrone. Anthrone undergoes a keto to enol isomerization to anthrol, which is a fluorescent dye that absorbs UV light and emits in the visible (remember the demo in class).



The Clemmensen reduction can also be used to form ethyl benzene:



At first it might appear that a simpler way of making ethyl benzene would be to use ethyl chloride instead of acetyl chloride, but other products would be formed:



This unwanted products would be formed because ethyl benzene is more reactive than benzene (inductive effect). Once some ethyl benzene is formed, it will react with the ethyl chloride instead of the unreacted benzene. This does not occur with acetophenone because it is an electron withdrawing group and is less reactive than benzene.