Week 1

AROMATIC COMPOUNDS

Aromatic compounds represent another example of unsaturated hydrocarbons. The physical properties are similar to other hydrocarbons; they have low melting points and boiling points and are water insoluble.

Aromatic compounds were originally named because many simple compounds in this family have characteristic odors. Today, the word **aromatic refers to compounds that contain a benzene ring,** or rings that react in a similar fashion to benzene.

Benzene (C_6H_6), the simplest and most widely known aromatic compound, contains a six-membered ring and three double bonds. Each carbon is surrounded by three groups, making it trigonal planar and sp2 hybidized. Thus, **benzene is a planar molecule,** and all bond angles are **120°.**
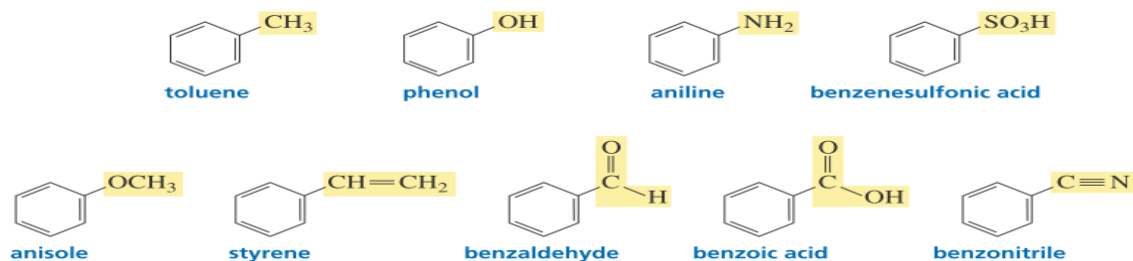
NOMENCLATURE OF BENZENE DERIVATIVES
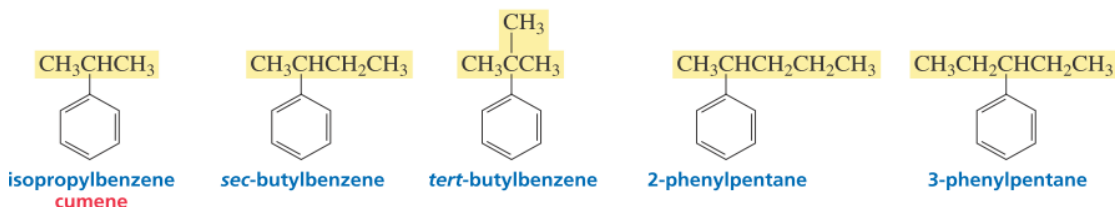## MONOSUBSTITUTED BENZENES

To name a benzene ring with one substituent, name the substituent and add the word *benzene.* Carbon substituents are named as alkyl groups. When a halogen is a substituent, name the halogen by changing the *-ine* ending of the name of the halogen to the suffix *-o*; for example, chlor*ine* → chlor*o*.


ethyl group | butyl group | chloro group
ethylbenzene | butylbenzene | chlorobenzene
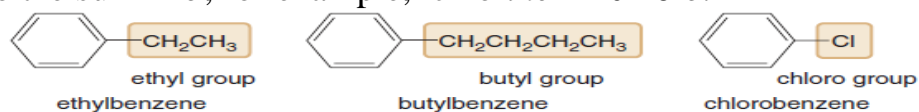
Many monosubstituted benzenes, such as those with methyl (CH_3-), hydroxyl ($-OH$), and amino ($-NH_2$) groups, have common names that you must learn, too.

toluene — phenol — aniline — benzenesulfonic acid

anisole — styrene — benzaldehyde — benzoic acid — benzonitrile

With the exception of toluene, benzene rings with an alkyl substituent are named as alkyl-substituted benzenes or as phenyl-substituted alkanes.


isopropylbenzene — sec-butylbenzene — tert-butylbenzene — 2-phenylpentane — 3-phenylpentane
cumene

When a benzene ring is a substituent, it is called a phenyl group. A benzene ring with a methylene group is called a benzyl group.

a phenyl group   a benzyl group   chloromethylbenzene / benzyl chloride   diphenyl ether   dibenzyl ether
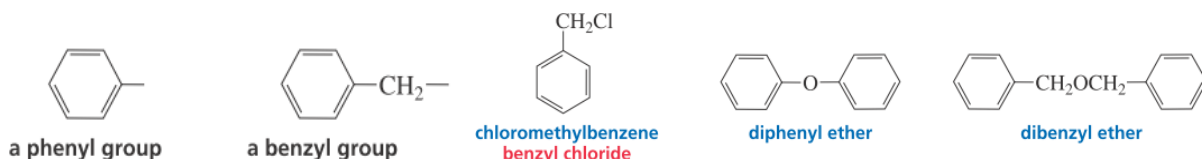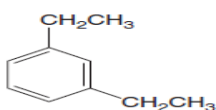
DISUBSTITUTED BENZENES

There are three different ways that two groups can be attached to a benzene ring, so a prefix, ortho, meta, or para is used to designate the relative position of the two substituents. Ortho, meta, and para are also abbreviated as *o, m,* and *p,* respectively.
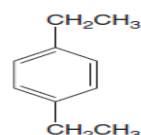

| 1,2-Disubstituted benzene ortho isomer	1,3-Disubstituted benzene meta isomer	1,4-Disubstituted benzene para isomer
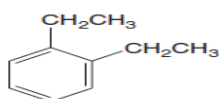
ortho-diethylbenzene
or
o-diethylbenzene
or
1,2-diethylbenzene

meta-diethylbenzene
or
m-diethylbenzene
or
1,3-diethylbenzene

para-diethylbenzene
or
p-diethylbenzene
or
1,4-diethylbenzene

If the two groups on the benzene ring are different, alphabetize the name of the substituents preceding the word benzene. If one of the substituents is part of a common root, name the molecule as a derivative of that mono substituted benzene.

1-bromo-3-chlorobenzene

1-chloro-3-methylbenzene
or 3-chlorotoluene
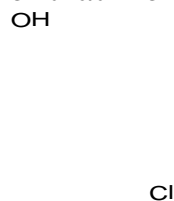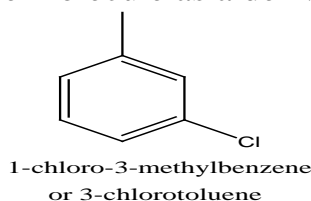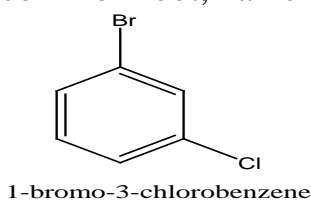
POLYSUBSTITUTED BENZENES

For three or more substituents on a benzene ring:
1. Number to give the lowest possible numbers around the ring.
2. Alphabetize the substituent names.
3. When substituents are part of common roots, name the molecule as a derivative of that mono substituted benzene. The substituent that comprises the common root is located at C_1, but the "1" is omitted from the name.

| Examples of naming polysubstituted benzenes		
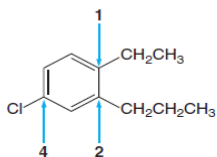
• Assign the lowest set of numbers.
• Alphabetize the names of all the substituents.
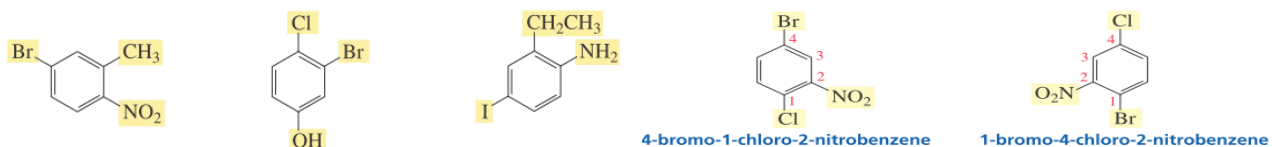
4-chloro-1-ethyl-2-propylbenzene
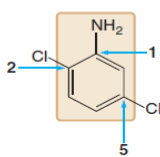
• Name the molecule as a derivative of the common root **aniline.**
• Designate the position of the NH_2 group as "1," and then assign the lowest possible set of numbers to the other substituents.

2,5-dichloro**aniline**

(TNT)

2

4-bromo-1-chloro-2-nitrobenzene   1-bromo-4-chloro-2-nitrobenzene
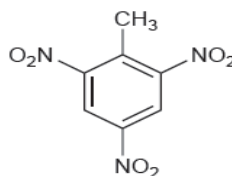
An aryl group (Ar) is the general term for either a phenyl group or a substituted phenyl group.

Resonance stabilization energy

Each π- electron of benzene ring is shared by all six carbons. The six π-electrons are delocalized they roam freely within the doughnut-shaped clouds that lie over and under the ring of carbon atoms. Consequently, benzene can be represented by a hexagon containing either dashed lines or a circle, to symbolize the six delocalized electrons. The approximate structure with localized electrons is called a **resonance contributor**, a **resonance structure**, or a **contributing resonance structure.** The actual structure with delocalized electrons is called a **resonance hybrid**. The actual structure of benzene is a Kekulé structure with delocalized electrons.
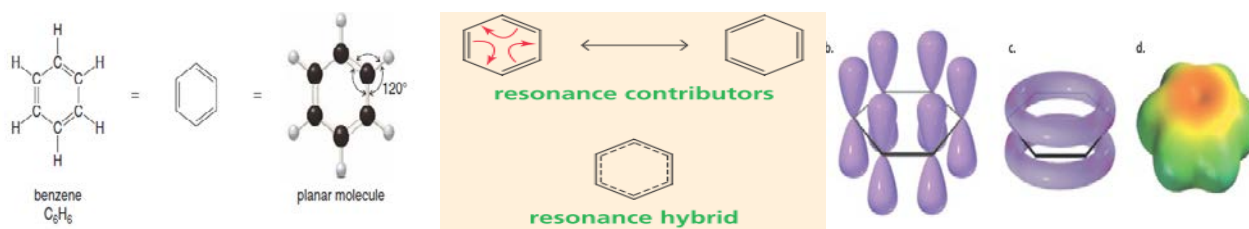
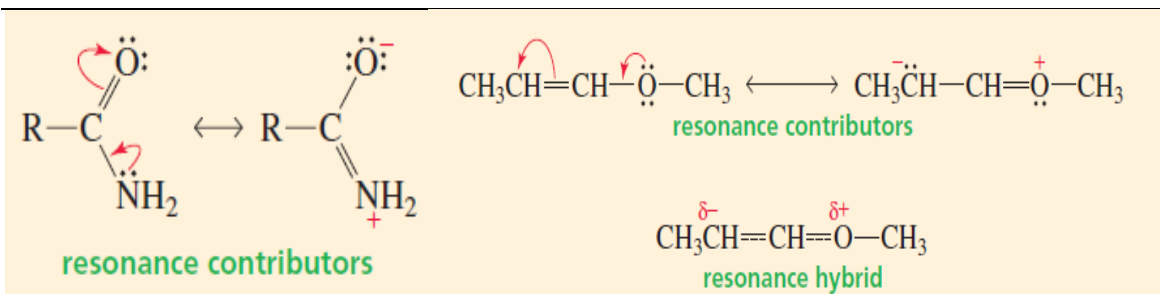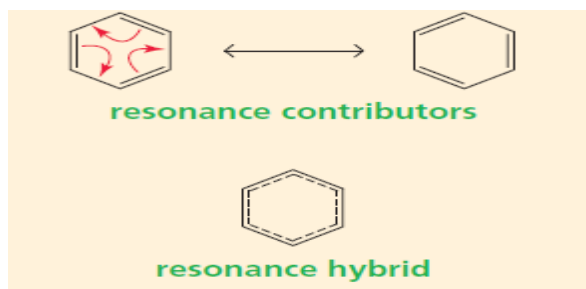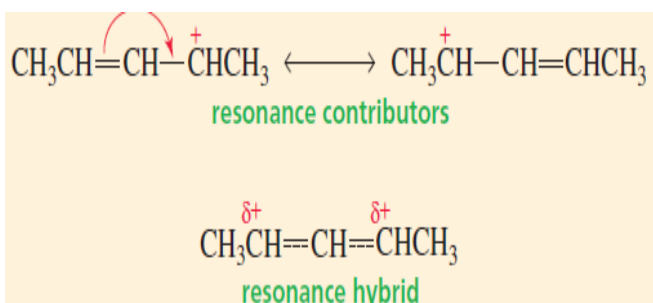Compounds such as benzene with unusually large resonance (36kcal) energies are called **aromatic compounds**.

Rules for Drawing Resonance Contributors

In drawing resonance contributors, the electrons in one resonance contributor are moved to generate the next resonance contributor. As you draw resonance contributors, keep in mind the following constraints:

1. Only electrons move. The nuclei of the atoms never move.
2. The only electrons that can move are π- electrons (electrons in π-bonds) and lone-pair electrons.
3. The total number of electrons in the molecule does not change.

The electrons can be moved in one of the following ways:
1. Move π- electrons toward a positive charge or toward a π-bond .
2. Move lone-pair electrons toward a π- bond .
3. Move a single nonbonding electron toward a π- bond .

CH$_3$CH=CH—$\overset{+}{C}$HCH$_3$ ⟷ CH$_3\overset{+}{C}$H—CH=CHCH$_3$
resonance contributors

resonance contributors

CH$_3$CH=$\overset{\delta+}{C}$H==$\overset{\delta+}{C}$HCH$_3$
resonance hybrid

resonance hybrid

R—C(=Ö:)(NH$_2$) ⟷ R—C(—:Ö:⁻)(=NH$_2$⁺)
resonance contributors

CH$_3$CH=CH—$\overset{..}{\ddot{O}}$—CH$_3$ ⟷ CH$_3\overset{-}{C}$H—CH=$\overset{+}{\ddot{O}}$—CH$_3$
resonance contributors

CH$_3$CH=$\overset{\delta-}{C}$H==$\overset{\delta+}{O}$—CH$_3$
resonance hybrid

an *sp^3* hybridized carbon cannot accept electrons

CH$_3$CH=CH—$\overset{..}{N}$HCH$_3$ ⟷ CH$_3\overset{-}{C}$H—CH=$\overset{+}{N}$HCH$_3$
delocalized electrons

CH$_3$CH=CH—CH$_2$—$\overset{..}{N}$H$_2$
localized electrons

CH$_3$—CH=CH—$\overset{.}{C}$H$_2$ ⟷ CH$_3$—$\overset{.}{C}$H—CH=CH$_2$
resonance contributors

CH$_3$—$\overset{\delta\cdot}{C}$H==CH==$\overset{\delta\cdot}{C}$H$_2$
resonance hybrid
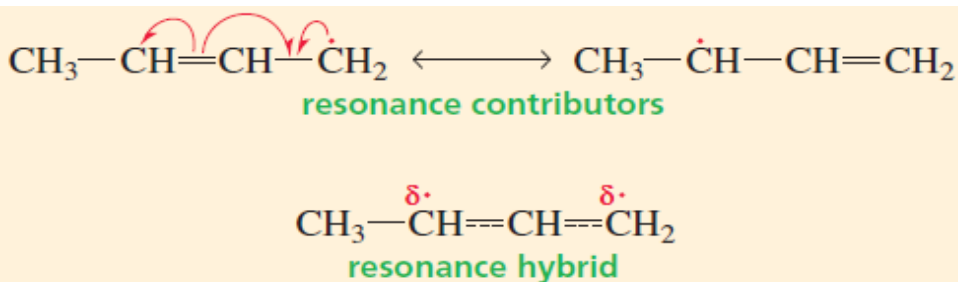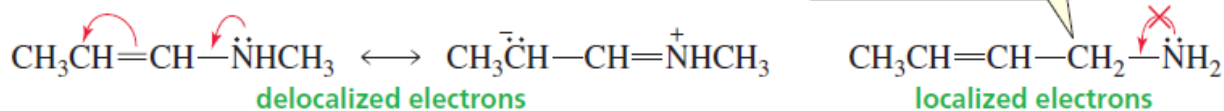
Aromaticity
How can we tell whether a compound is aromatic by looking at its structure?
To be classified as aromatic, a compound must meet both of the following criteria:
- 1. Cyclic
- 2. Planner
- 3. All atoms must be SP^2 (each atom in the ring must have an unhybridized *p* orbital).
- 4. All double bonds must be conjugated
- 5. Obey Hückel's rule which state that any aromatic compound must contain (**4n+2**) π- electrons where n= 0, 1, 2, 3, …

Consequently a compound is more stable than its open-chain counterpart.
Anti- and Non-aromatic

4

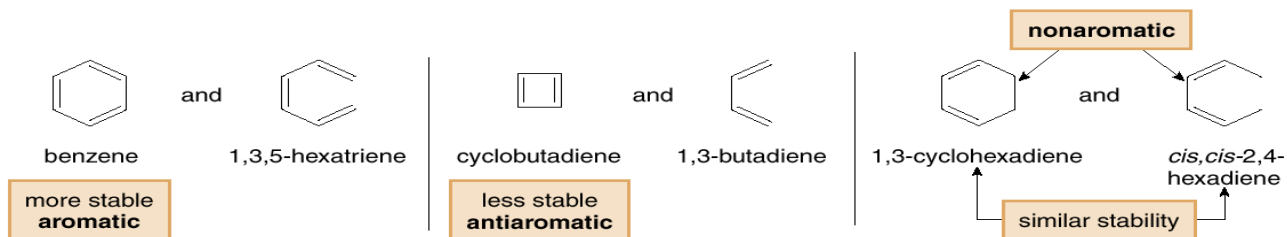Considering aromaticity, a compound can be classified in one of three ways:

1. Aromatic—A cyclic, planar, completely conjugated compound with $4n + 2$ π electrons.
2. Anti-aromatic—A cyclic, planar, completely conjugated compound with $4n$ π electrons.
3. Not aromatic (non-aromatic) A compound that lacks one (or more) of the following requirements for aromaticity: being cyclic, planar, and completely conjugated.

Note: the relationship between each compound type and a similar open-chained molecule having the same number of π electrons.

- An aromatic compound is *more* stable than a similar acyclic compound having the same number of π electrons. Benzene is more stable than 1,3,5-hexatriene.

- An antiaromatic compound is *less* stable than an acyclic compound having the same number of π electrons. Cyclobutadiene is less stable than 1,3-butadiene.

- A compound that is not aromatic is *similar* in stability to an acyclic compound having the same number of π electrons. 1,3-Cyclohexadiene is similar in stability to *cis,cis*-2,4-hexadiene, so it is not aromatic.

| benzene | and | 1,3,5-hexatriene | cyclobutadiene | and | 1,3-butadiene | 1,3-cyclohexadiene | and | *cis,cis*-2,4-hexadiene |

more stable aromatic — **less stable antiaromatic** — nonaromatic — similar stability

Hückel's rule and aromaticity
Examples of systems that obey the Hückel rule include:

Hückel's Rule

4n+2:	2	6	10	14	18	22	26
4n:	4	8	12	16	20	24	28

Benzene is aromatic and especially stable because it contains 6 π electrons. Cyclobutadiene is anti-aromatic and especially unstable because it contains 4 π electrons.

5

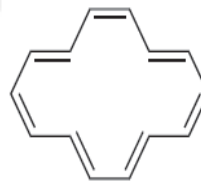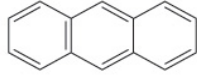| Benzene An aromatic compound | Cyclobutadiene An antiaromatic compound |

$4n + 2 = 4(1) + 2 =$
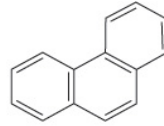6 π electrons
aromatic

$4n = 4(1) =$
4 π electrons
antiaromatic
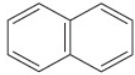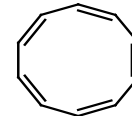
naphthalene
10 π electrons

anthracene
14 π electrons

phenanthrene
14 π electrons

[10] annulene

Monocyclic hydrocarbons with alternating single and double bonds are called **annulenes**. A prefix in brackets denotes the number of carbons in the ring. Example:
cyclotetradeca-1,3,5,7,9,11,13-heptaene and cyclooctadeca-1,3,5,7,9,11,13,15,17-nonaene.

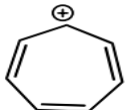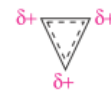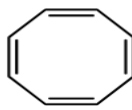Q: Indicate which of the following are aromatic and antiaromatic?

a)

b)

resonance contributors of the cyclopropenyl cation
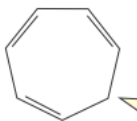
c)

d)

resonance hybrid

cycloheptatriene sp^3 cyclopentadiene sp^3 cyclopropene   cyclopropenyl cation   cyclopropenyl anion

For the compound to be aromatic, these MOs must be completely filled with electrons, so the "magic numbers" for aromaticity fit Hückel's $4n + 2$ rule

6

REACTIONS OF AROMATIC COMPOUNDS

Aromatic compounds undergo a characteristic type of reaction. In contrast to the alkenes aromatic compounds undergo **substitution** *not* addition. Substitution is a reaction in which an atom is *replaced* by another atom or a group of atoms. As a consequence of the π-electrons above and below the plane of its ring, benzene is a nucleophile. It will, therefore, react with an electrophile (E+).When an electrophile attaches itself to a benzene ring, a carbocation intermediate is formed.

substitution of H by X

carbocation intermediate
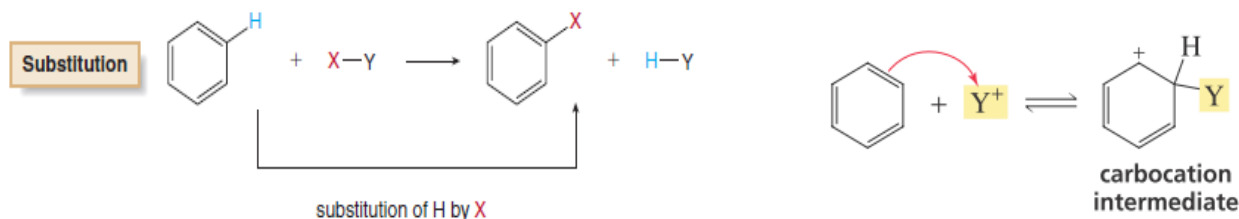
General Mechanism for Electrophilic Aromatic Substitution Reactions

In an electrophilic aromatic substitution reaction, an electrophile substitutes for a hydrogen of an aromatic compound.

general mechanism for electrophilic aromatic substitution
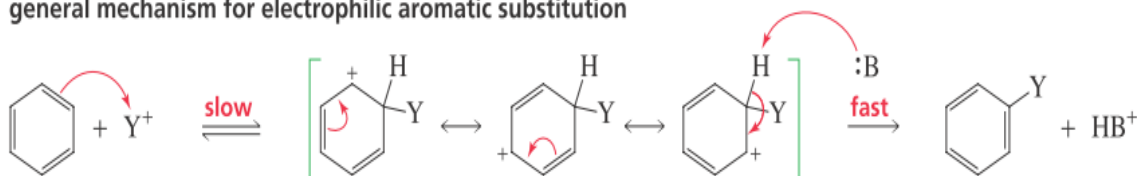
The following are the five most common electrophilic aromatic substitution reactions:
1. Halogenation: A bromine (Br), a chlorine (Cl), or an iodine (I) substitutes for a hydrogen.
2. Nitration: A nitro group substitutes for a hydrogen.
3. Sulfonation: A sulfonic acid group substitutes for a hydrogen.
4. Friedel–Crafts acylation: An acyl group substitutes for a hydrogen.
5. Friedel–Crafts alkylation: an alkyl (R) group substitutes for a hydrogen.

All five electrophilic aromatic substitution reactions differ only in how the electrophile(Y^+) needed to start the reaction is generated. Once the electrophile is formed, all five reactions follow the same two-step mechanism for electrophilic aromatic substitution.

Halogenation of Benzene

The bromination or chlorination of benzene requires a Lewis acid such as ferric bromide or ferric chloride. Benzene reacts with Cl_2 in the presence of an iron catalyst ($FeCl_3$) to yield chlorobenzene.

Chlorobenzene is an **aryl halide,** an organic halide with the halogen bonded directly to the aromatic ring. Reaction with chlorine is called **chlorination.** In chlorination, a Cl atom substitutes for a hydrogen atom on the benzene ring.

7

bromination

bromobenzene   chlorobenzene

mechanism for bromination

Nitration of Benzene
Nitration of benzene with nitric acid requires sulfuric acid as a catalyst.

nitrobenzene

mechanism for nitration

nitric acid   nitronium ion

$+ \ HSO_4^-$

Sulfonation of Benzene
Fuming sulfuric acid (a solution of SO_3 in sulfuric acid) or concentrated sulfuric acid is used to sulfonate aromatic rings.

benzenesulfonic acid

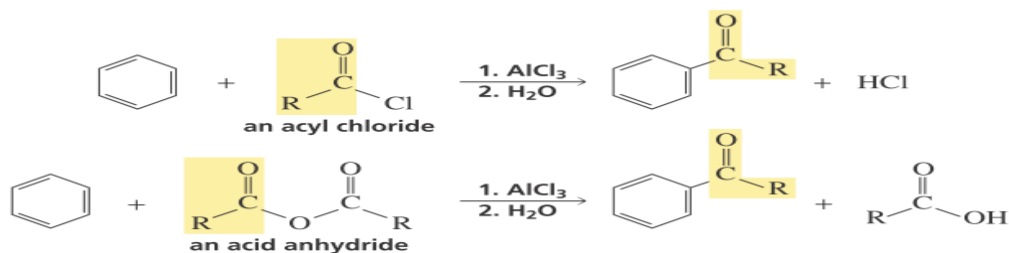**mechanism for sulfonation**

sulfuric acid

8

Friedel–Crafts Acylation of Benzene

Two electrophilic substitution reactions bear the names of chemists Charles Friedel and James Crafts. Friedel–Crafts acylation places an acyl group on a benzene ring, and Friedel–Crafts alkylation places an alkyl group on a benzene ring.
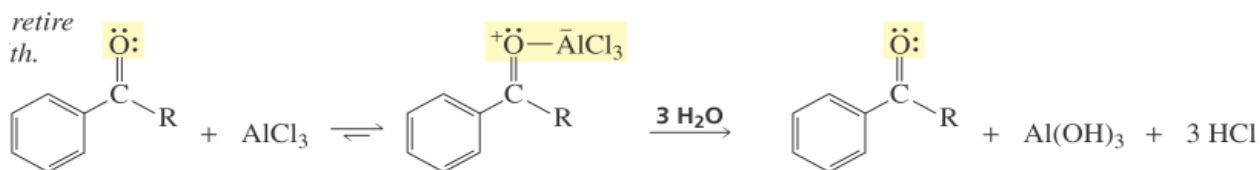
Friedel–Crafts acylation

**mechanism for Friedel–Crafts acylation**
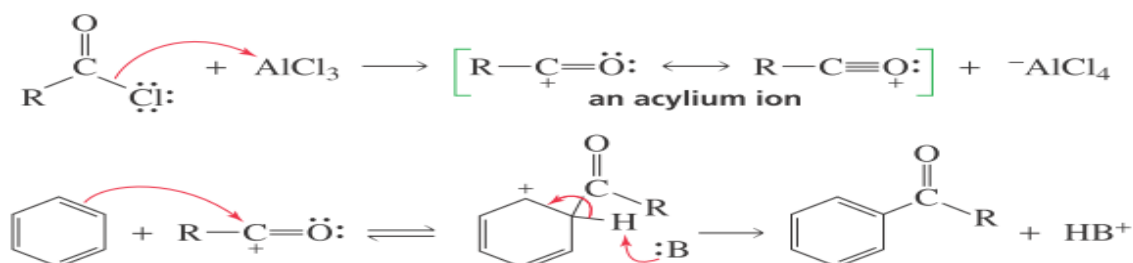
Because the product of a Friedel–Crafts acylation reaction contains a carbonyl group that can complex with $AlCl_3$ Friedel–Crafts acylation reactions must be carried out with more than one equivalent of $AlCl_3$. When the reaction is over, water is added to the reaction mixture to liberate the product from the complex.


Friedel–Crafts Alkylation of Benzene

The Friedel–Crafts alkylation reaction substitutes an alkyl group for a hydrogen.

mechanism for Friedel–Crafts alkylation
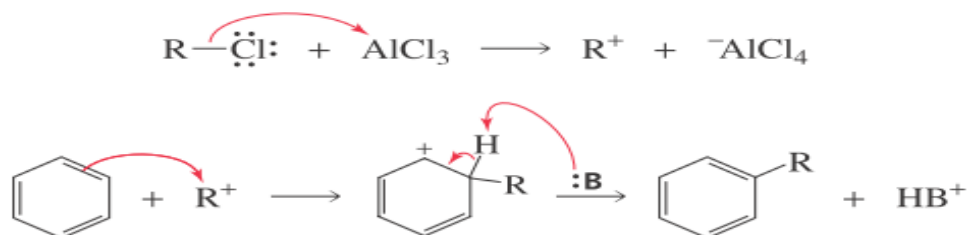
Alkyl-substituted benzene is more reactive than benzene. Therefore, to prevent further alkylation of the alkyl-substituted benzene, a large excess of benzene is used in Friedel–Crafts alkylation reactions. This approach ensures that the electrophile is more likely to encounter a molecule of benzene than a molecule of alkyl-substituted benzene.

9

Recall that a carbocation will rearrange if rearrangement leads to a more stable carbocation. When the carbocation can rearrange in a Friedel–Crafts alkylation reaction, the major product will be the product with the rearranged alkyl group on the benzene ring. The relative amounts of rearranged and un rearranged product depend on the increase in carbocation stability achieved as a result of the rearrangement. For example:
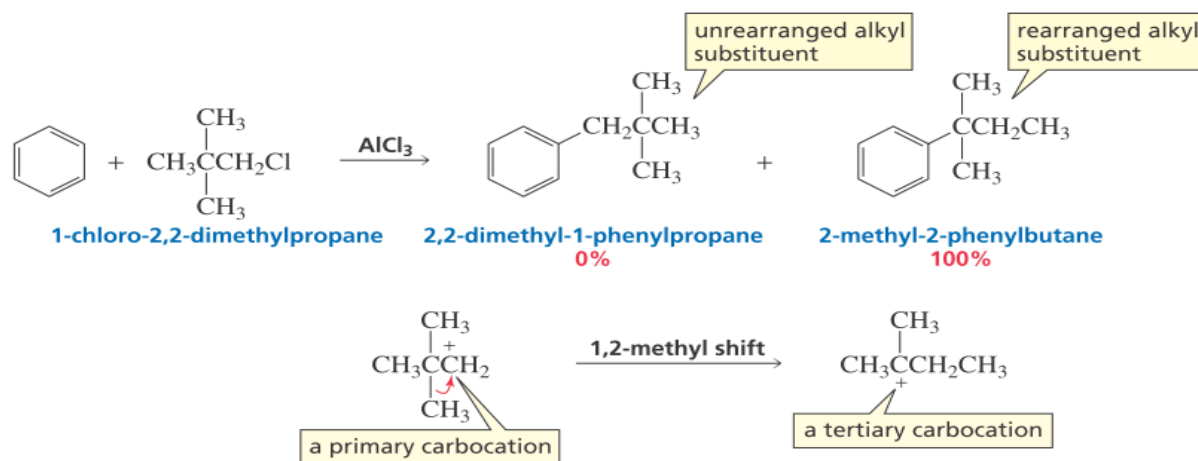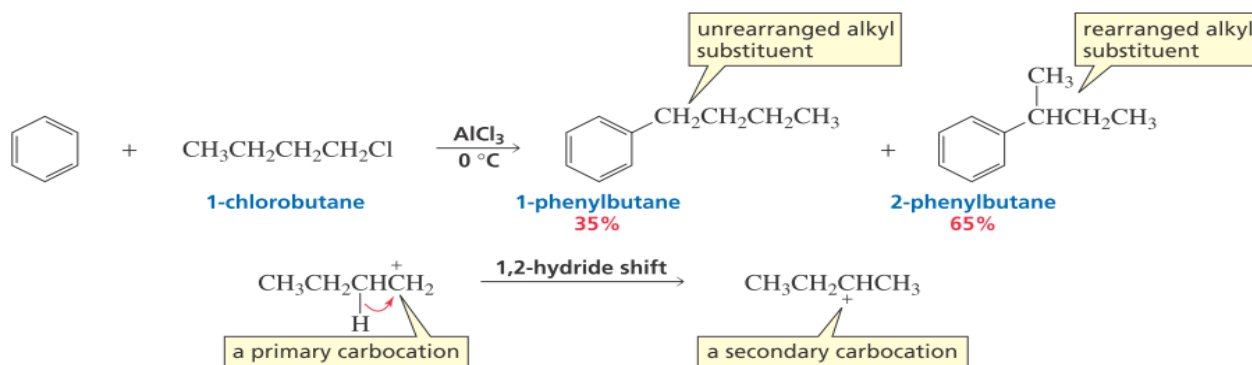
In addition to reacting with carbocations generated from alkyl halides, benzene can react with carbocations generated from the reaction of an alkene or an alcohol with an acid.
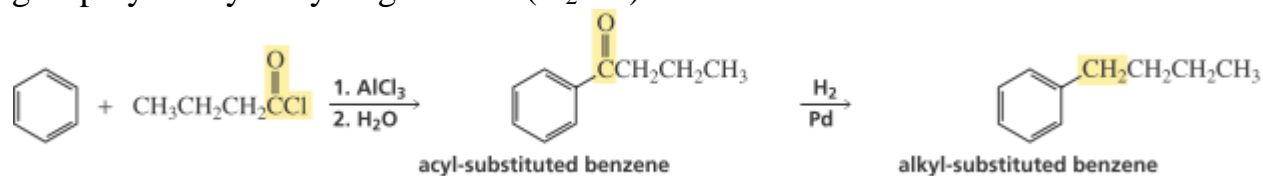
Alkylation of Benzene by Acylation–Reduction

It is not possible to obtain a good yield of an alkyl benzene containing a straight-chain alkyl group via a Friedel–Crafts alkylation reaction, because the incipient primary carbocation will rearrange to a more stable carbocation.
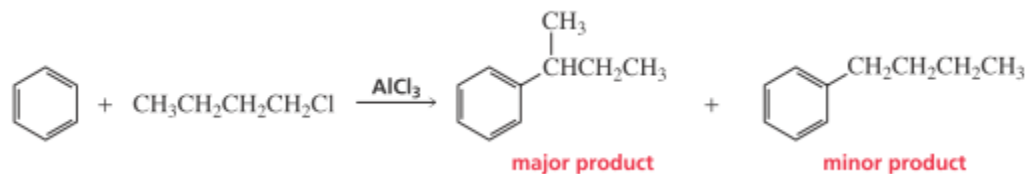
Acylium ions, however, do not rearrange. Consequently, a straight-chain alkyl group can be placed on a benzene ring by means of a Friedel–Crafts acylation reaction, followed by reduction of the carbonyl group to a methylene group. It is called a

reduction reaction because the two C-O bonds are replaced by two C-H bonds. Only a ketone carbonyl group that is adjacent to a benzene ring can be reduced to a methylene group by catalytic hydrogenation. (H$_2$/Pd)

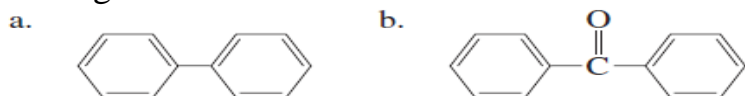acyl-substituted benzene   alkyl-substituted benzene

Besides avoiding carbocation rearrangements, another advantage of preparing alkyl substituted benzenes by acylation–reduction rather than by direct alkylation is that a large excess of benzene does not have to be used. Unlike alkyl-substituted benzenes, which are more reactive than benzene, acyl-substituted benzenes are less reactive than benzene, so they will not undergo additional Friedel–Crafts reactions.
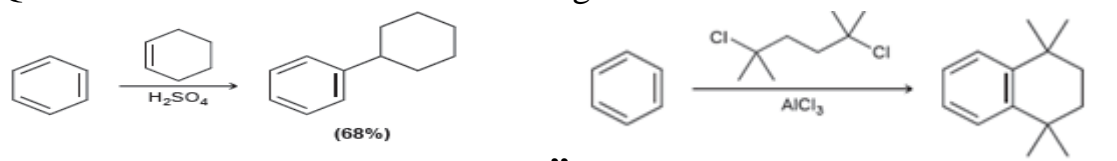
Q/ What would be the major product of a Friedel–Crafts alkylation reaction using the following alkyl halides?

a. CH_3CH_2Cl
b. $CH_3CH_2CH_2Cl$
c. $CH_3CH_2CH(Cl)CH_3$

d. $(CH_3)_3CCH_2Cl$
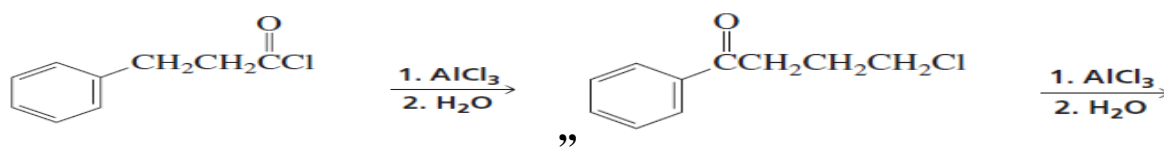e. $(CH_3)_2CHCH_2Cl$
f. $CH_2{=}CHCH_2Cl$

Q/ How could you prepare the following compounds with benzene as one of the starting materials?

a.

b.

Q/ Draw a mechanism for the following transformation:

(68%)

"

Q/ Give the products of the following reactions:

"

**The Effect of Substituents on Reactivity**

Like benzene, substituted benzenes undergo the five electrophilic aromatic substitution reactions halogenation, nitration, sulfonation, alkylation, and acylation. Now we need to find out whether substituted benzene is more reactive or less reactive than benzene itself. The answer depends on the substituent. Some substituents make the ring more reactive and some make it less reactive than benzene toward electrophilic aromatic substitution.

The slow step of an electrophilic aromatic substitution reaction is the addition of an electrophile to the nucleophilic aromatic ring to form a carbocation intermediate. Substituents that are capable of donating electrons into the benzene ring will stabilize both the carbocation intermediate and the transition state leading to its

11

formation, thereby increasing the rate of electrophilic aromatic substitution. In contrast, substituents that withdraw electrons from the benzene ring will destabilize the carbocation intermediate and the transition state leading to its formation, thereby decreasing the rate of electrophilic aromatic substitution .

relative rates of electrophilic substitution

Z donates electrons into the benzene ring

Y withdraws electrons from the benzene ring
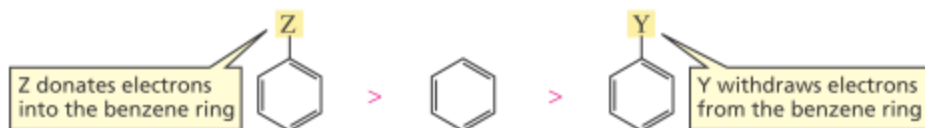
There are two ways substituents can donate or withdraw electrons into a benzene ring: **inductively and resonance.**

Inductive Electron Donation and Withdrawal

Donation of electrons through a σ bond is called inductive electron donation(+I). Alkyl substituents (such as CH_3) donate electrons inductively compared with a hydrogen. Notice that the electron-donating ability of an alkyl group—not the electron donating ability of a carbon atom—is compared with that of hydrogen. Carbon is actually slightly less electron donating than hydrogen (because C is more electronegative than H), but an alkyl group is more electron donating than hydrogen because of hyperconjugation.

substituent donates electrons inductively (compared with a hydrogen)

substituent withdraws electrons inductively (compared with a hydrogen)
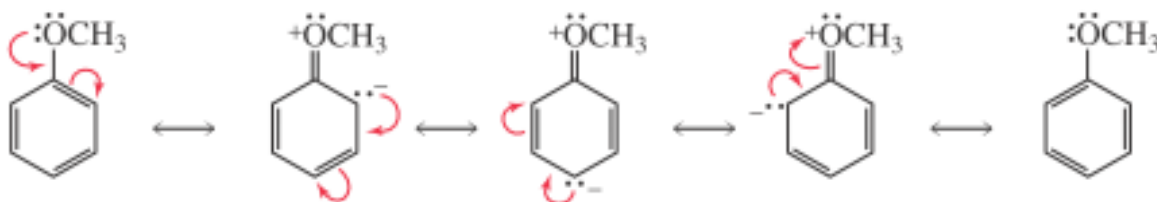
If a substituent is more electron withdrawing than hydrogen, it will withdraw the electrons away from the benzene ring more strongly than will a hydrogen. Withdrawal of electrons through σ- bond is called inductive electron withdrawal (-I). The ($^{+}NH_3$) group is a substituent that withdraws electrons inductively because it is more electronegative than a hydrogen.

### Resonance Electron Donation and Withdrawal

If a substituent has a lone pair on the atom that is directly attached to the benzene ring the lone pair can be delocalized into the ring; these substituents are said to donate electrons by resonance. (+M). Substituents such as NH_2, OH, OR, and Cl donate electrons by resonance. These substituents also withdraw electrons inductively because the atom attached to the benzene ring is more electronegative than hydrogen.

donation of electrons into a benzene ring by resonance

12

If a substituent is attached to the benzene ring by an atom that is doubly or triply bonded to a more electronegative atom, the π-electrons of the ring can be delocalized onto the substituent; these substituents are said to withdraw electrons by resonance (-M) . Substituents such as C=O, C≡N and NO$_2$ withdraw electrons by resonance. These substituents also withdraw electrons inductively because the atom attached to the benzene ring has a full or partial positive charge and, therefore, is more electronegative than a hydrogen.

**withdrawal of electrons from a benzene ring by resonance**
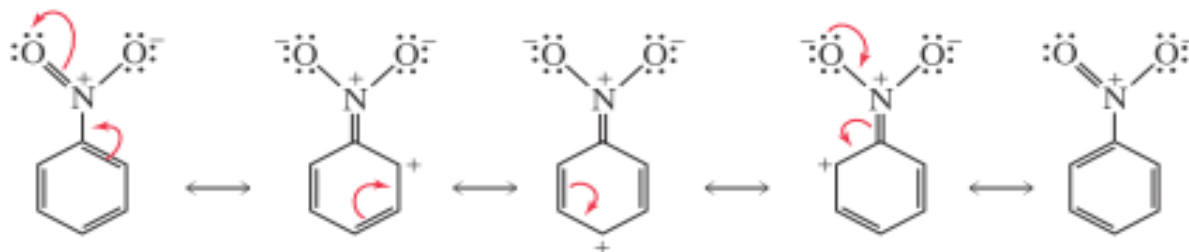
Relative Reactivity of Substituted Benzenes

The substituents shown in Table below are listed according to how they affect the reactivity of the benzene ring toward electrophilic aromatic substitution compared with benzene—in which the substituent is a hydrogen.
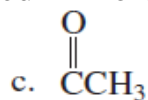
All the strongly activating substituents donate electrons into the ring by resonance and withdraw electrons from the ring inductively. (+M >>> -I).

strongly activating substituents
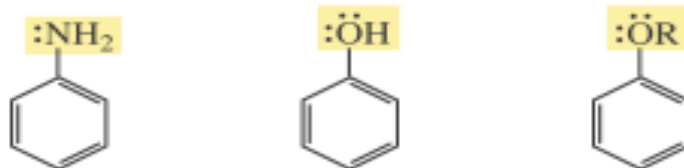
Q5/ For each of the following substituents, indicate whether it has(-M, +M, -I, or +I) (inductive effects should be compared with a hydrogen; remember that many substituents can be characterized in more than one way):

a. Br

b. CH$_2$CH$_3$

$$\text{O}$$
c. $\overset{\|}{\text{C}}$CH$_3$

d. NHCH$_3$

e. OCH$_3$

f. $\overset{+}{\text{N}}$(CH$_3$)$_3$

A list of activators and deactivators by category:

The moderately activating substituents can donate electrons by resonance in two competing directions: into the ring and away from the ring. The fact that these substituents are activators indicates that, despite their diminished resonance electron donation into the ring, overall they donate electrons by resonance more strongly than they withdraw electrons inductively.(+M > -I).
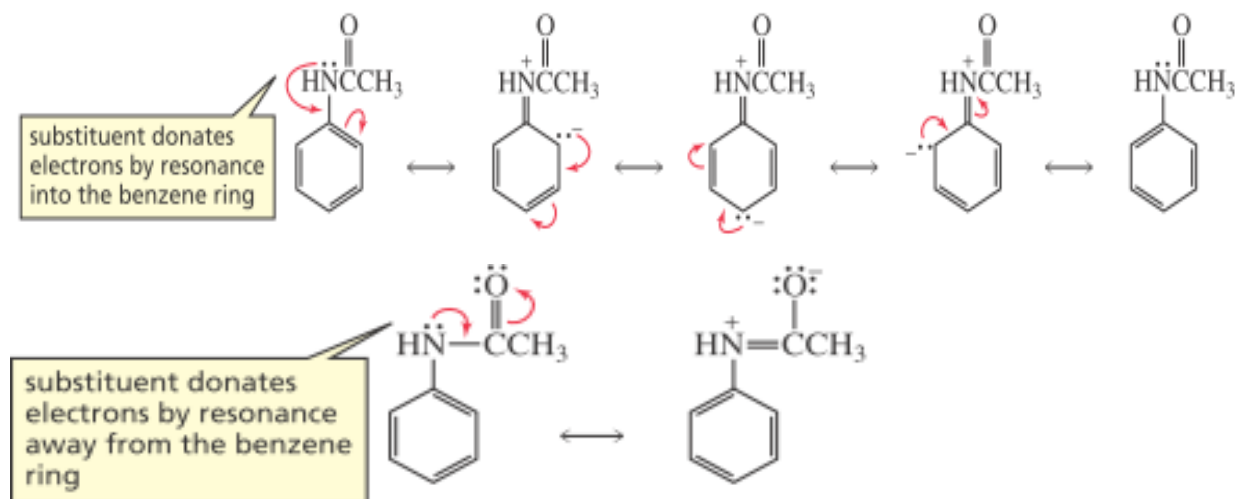

The halogens are weakly deactivating substituents; because (-I > +M).

The moderately deactivating substituents all have carbonyl groups directly attached to the benzene ring. Carbonyl groups withdraw electrons both inductively and by resonance.(-M, -I).

The strongly deactivating substituents are powerful electron withdrawers all have strong.(-M, -I). Except for the ammonium ions ($^+NH_3$, $^+NH_2R$, $^+NHR_2$ and $^+NR_3$), which have strong (-I) only. The ammonium ions have no resonance effect, but the positive charge on the nitrogen atom causes them to strongly withdraw electrons inductively.
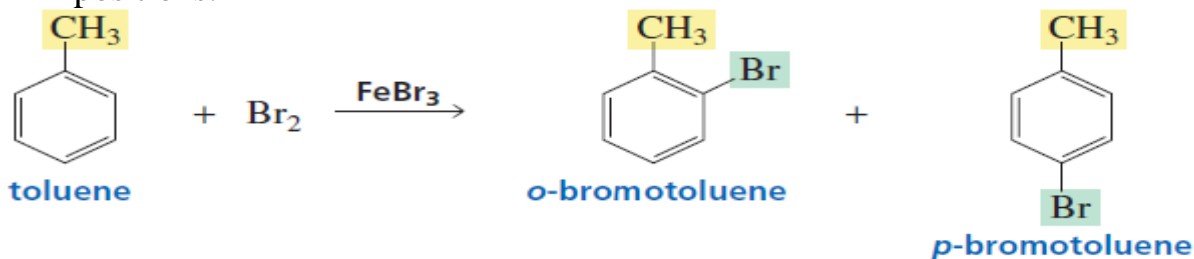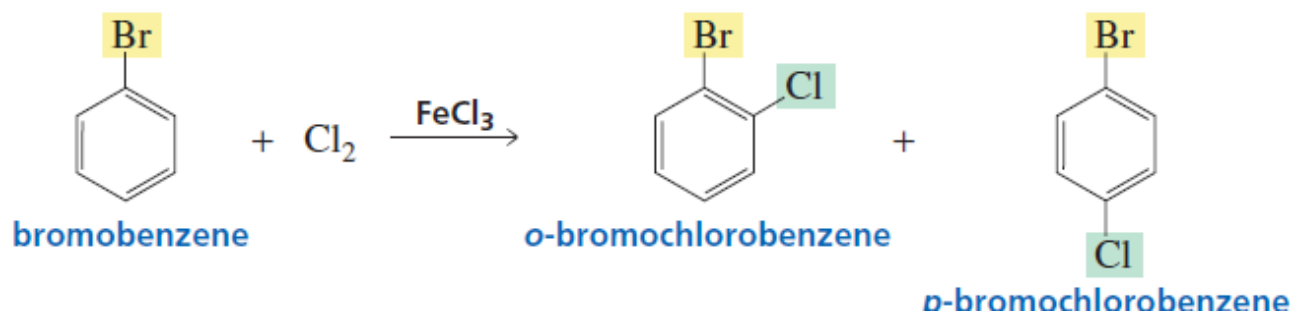
strongly deactivating substituents
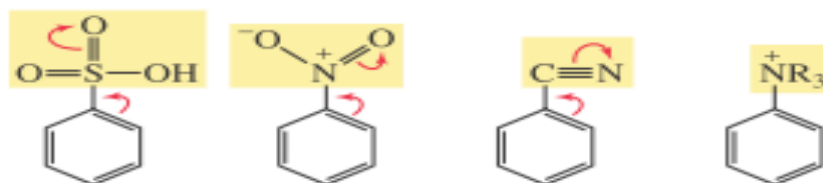
The Effect of Substituents on Orientation

The substituent already attached to the benzene ring determines the location of the new substituent. There are two possibilities: A substituent will direct an incoming substituent either to the ortho and para positions, or it will direct an incoming substituent to the meta position. All activating substituents and the weakly deactivating halogens are ortho–para directors, and all substituents that are more deactivating than the halogens are meta directors. Thus, the substituents can be divided into three groups:

1. All activating substituents direct an incoming electrophile to the ortho and para positions.
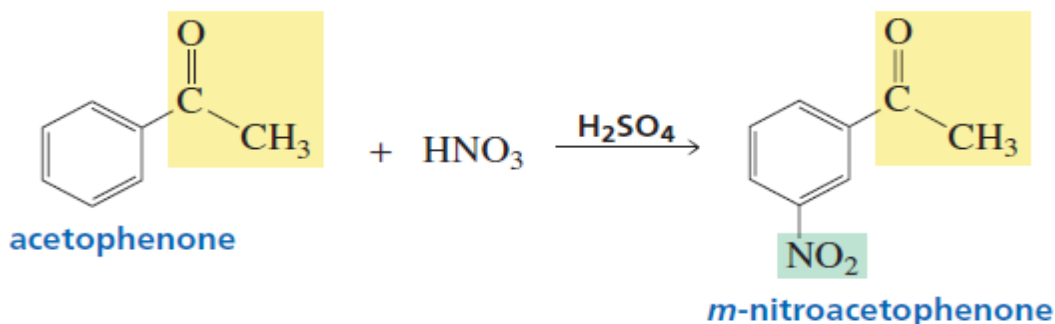

2. The weakly deactivating halogens also direct an incoming electrophile to the ortho and para positions.

3. All moderately deactivating and strongly deactivating substituents direct an incoming electrophile to the meta position. Why?

15

acetophenone

m-nitroacetophenone

To answer the above questions: we must look at the stability of the carbocation intermediate that is formed in the rate-determining step in all cases.

The relative stabilities of the three carbocations (o,m &p) enable us to determine the preferred pathway of the reaction because the more stable the carbocation, the less energy required to make it and the more likely it is that it will be formed.
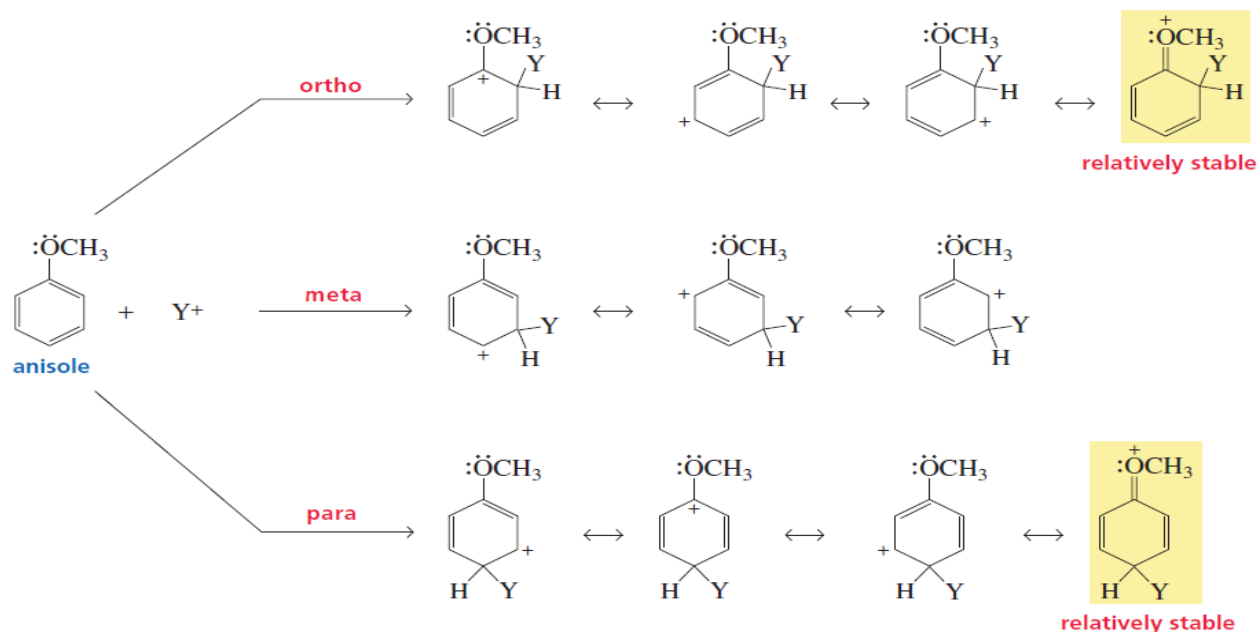
1/ **If a substituent donates electrons inductively—a methyl group, for example**:
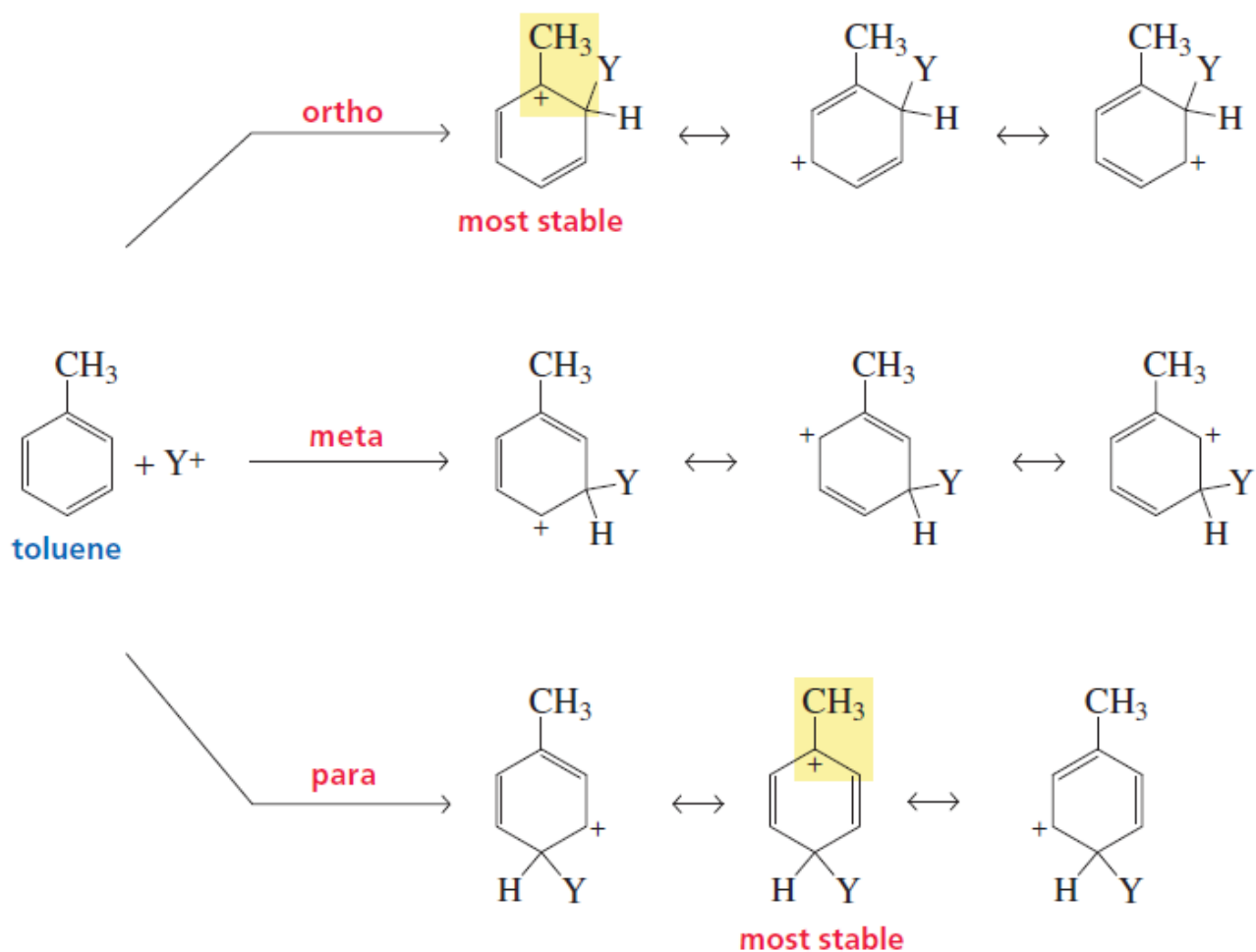
The most stable carbocation is the one that a positive charge attached directly to electron donating substituent, the substituent can stabilize the resonance structure by inductive electron donation. These relatively stable resonance contributors are obtained only when the incoming group is directed to an ortho or para position. Thus, any substituent that donates electrons inductively is an ortho–para director.

16

2/ If a substituent donates electrons by resonance, the carbocations formed by putting the incoming electrophile on the ortho and para positions have a fourth resonance contributor (Figure below). This is an especially stable resonance contributor because it is the only one whose atoms (except for hydrogen) all have complete octets. Therefore, all substituents that donate electrons by resonance are ortho–para directors.


3/ Substituents with a positive charge or a partial positive charge on the atom attached to the benzene ring, withdraw electrons inductively from the benzene ring, and most withdraw electrons by resonance as well. The least stable have a positive charge on each of two adjacent atoms, so the most stable carbocation is formed when the incoming electrophile is directed to the meta position.
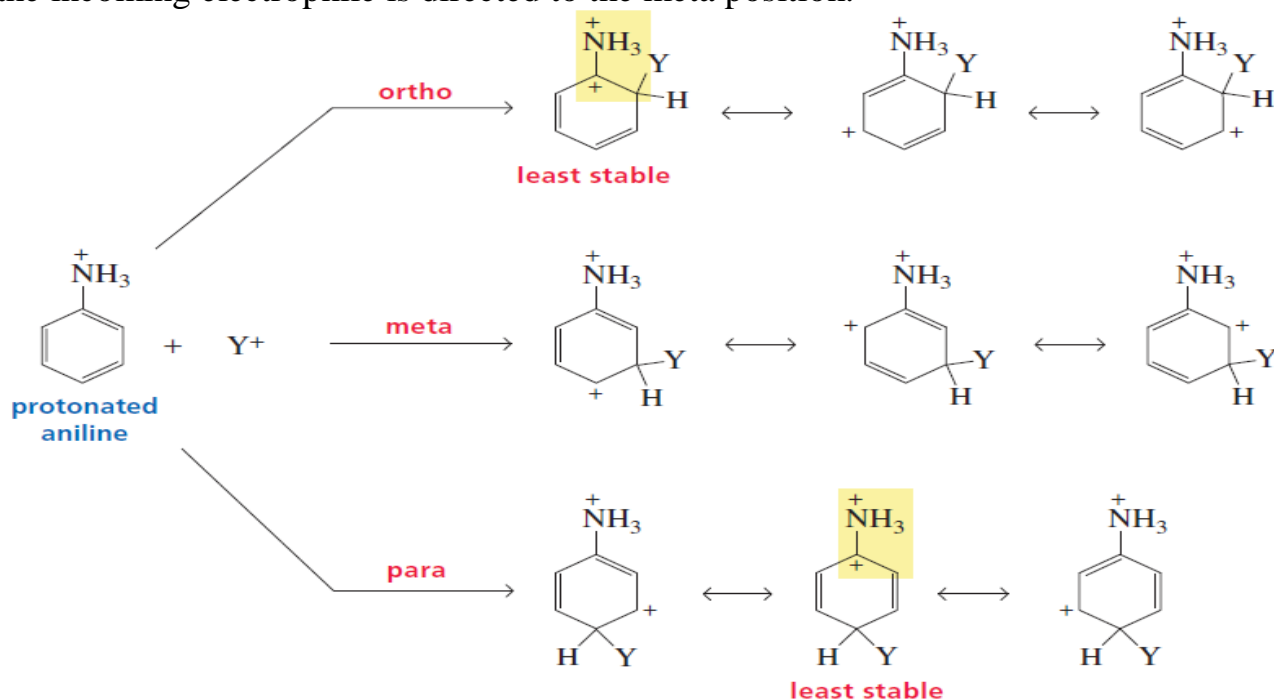
An activating group activates all positions of the benzene ring; even the positions meta to it are more reactive than any single position in benzene itself. It directs ortho and para simply because it activates the ortho and para positions much more than it does the meta. A deactivating group deactivates all positions in the ring, even the positions meta to it. It directs meta simply because it deactivates the ortho and para positions even more than it does the meta.

Q/ Draw the resonance contributors for nitrobenzene.

Q/ Are the following substituents ortho–para directors or meta directors?

a. $CH_2=CHC\equiv N$ c. CH_2OH e. CF_3

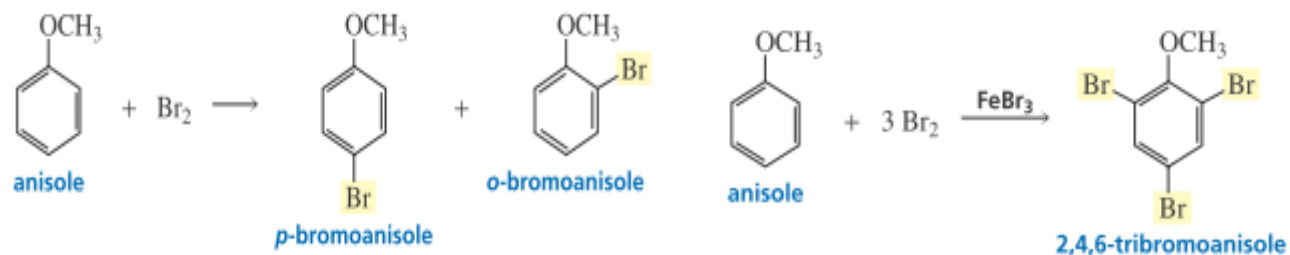b. NO_2 d. $COOH$ f. $N=O$
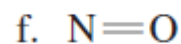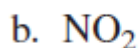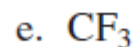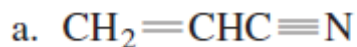
The Ortho–Para Ratio

When a benzene ring with an ortho–para-directing substituent undergoes an electrophylic aromatic substitution reaction, what percentage of the product is the ortho isomer and what percentage is the para isomer? Solely on the basis of probability, one would expect more of the ortho product because there are two ortho positions available to the incoming electrophile and only one para position. The ortho position, however, is satirically hindered, whereas the para position is not. Consequently, the para isomer will be formed preferentially if either the substituent on the ring or the incoming electrophile is large. The following nitration reaction illustrates the decrease in the ortho–para ratio with an increase in the size of the alkyl substituent:

18
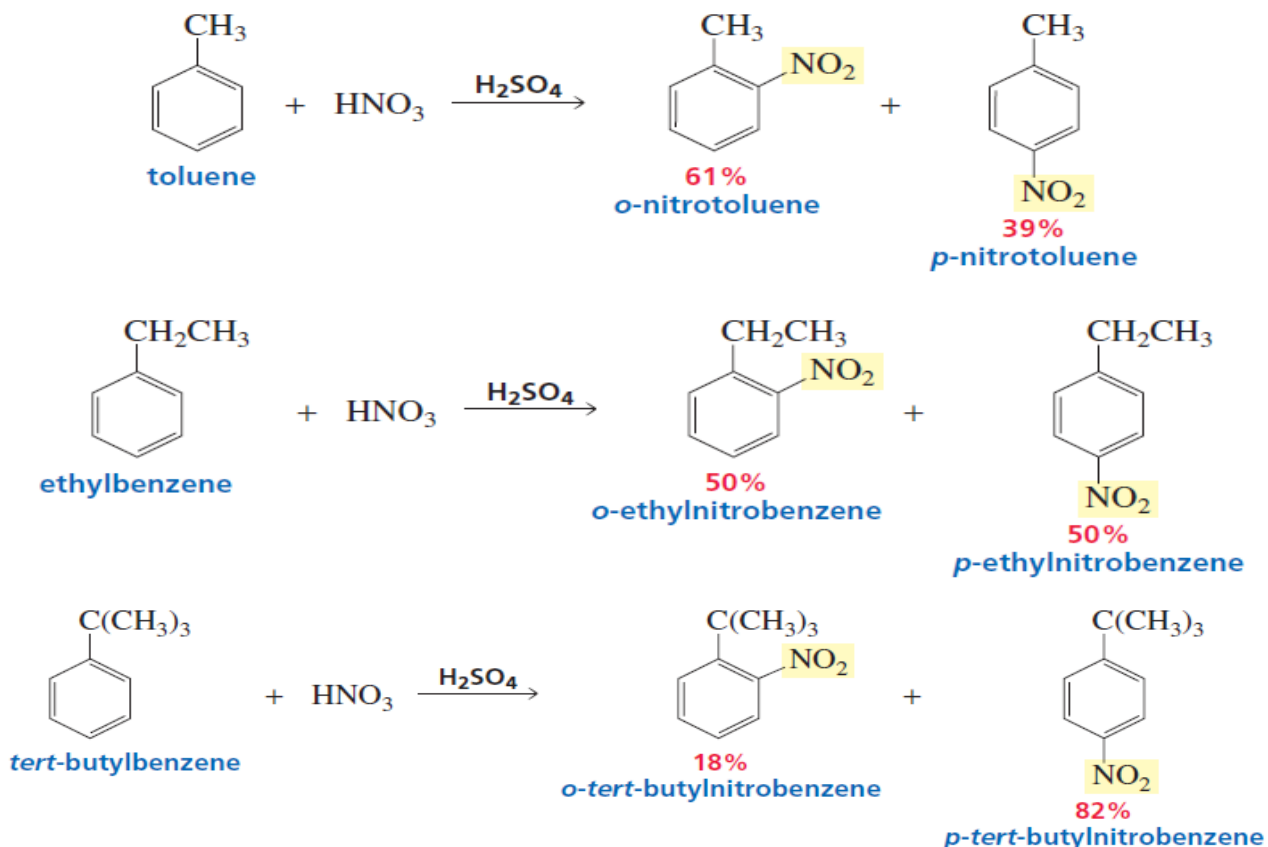
Additional Considerations Regarding Substituent Effects

It is important to know whether a substituent is activating or deactivating in determining the conditions needed to carry out a reaction. For example, methoxy and hydroxyl substituents are so strongly activating that halogenation is carried out without the Lewis acid (catalyst).

If the Lewis acid catalyst and excess bromine are used, the tribromide is obtained.

anisole   + Br₂ ⟶   p-bromoanisole   +   o-bromoanisole   ;   anisole + 3 Br₂ →(FeBr₃) 2,4,6-tribromoanisole

All Friedel–Crafts reactions require the Lewis acid catalyst. However, if there is a meta director the ring will be too unreactive to undergo either Friedel–Crafts acylation or Friedel–Crafts alkylation.

Some examples:

1/ Synthesis of meta-bromobenzenesulfonic acid?

The sulfonic acid group has to be placed on the ring first because that group will direct the bromo substituent to the desired meta position.

m-bromobenzenesulfonic acid
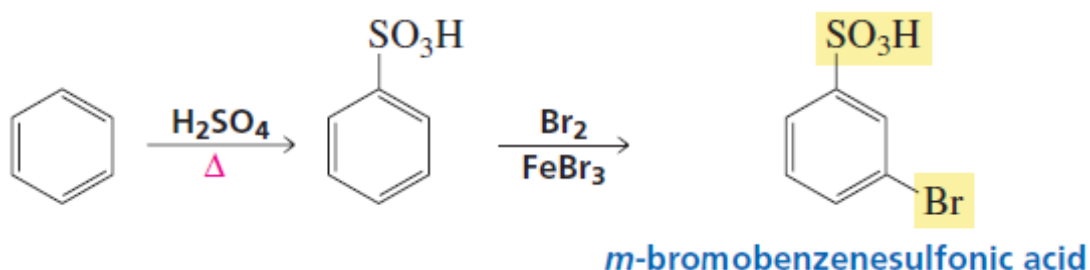
However, if the desired product is para-bromobenzenesulfonic acid, the order of the two reactions must be reversed because only the bromo substituent is an ortho - para director.

p-bromobenzenesulfonic acid   +   o-bromobenzenesulfonic acid
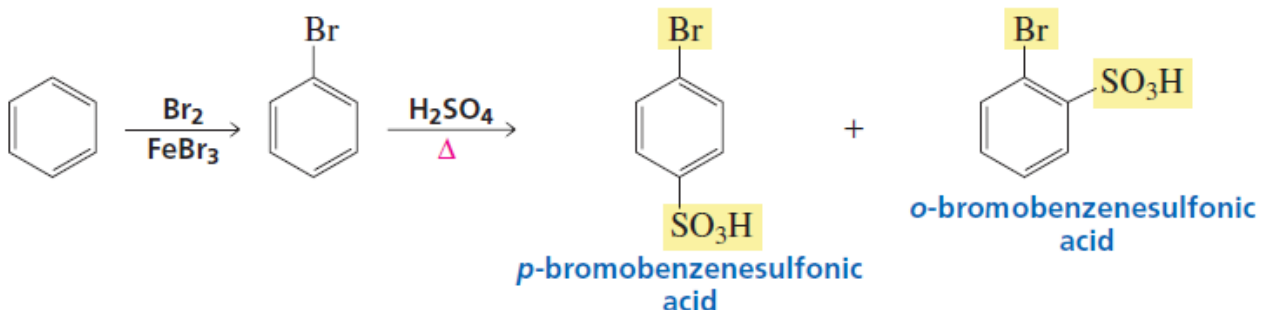
Both substituents of meta-nitroacetophenone are meta directors. However, the Friedel–Crafts acylation reaction must be carried out first because the benzene ring of nitrobenzene is too deactivated to undergo a Friedel–Crafts reaction.

m-nitroacetophenone
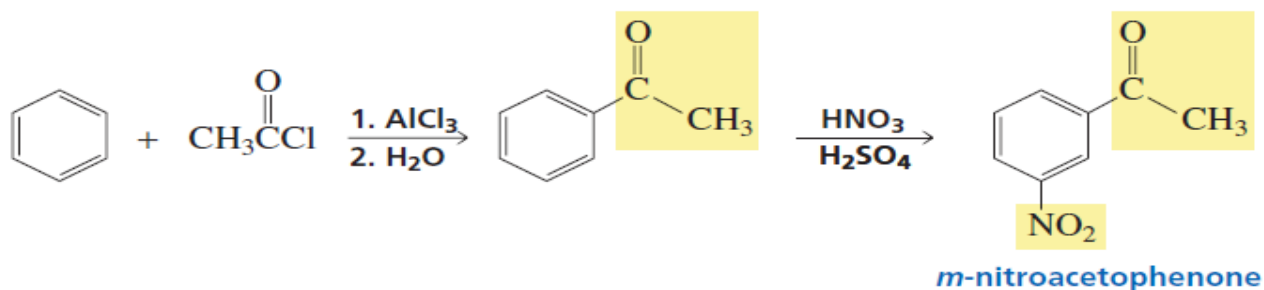
Q/ prepare p- and m- chlorobenzoic acid from toluene?

**Synthesis of Trisubstituted Benzenes**
When disubstituted benzene undergoes an electrophilic aromatic substitution reaction, the directing effect of both substituents has to be considered. If both substituents direct the incoming substituent to the same position, the product of the reaction is easily predicted.

both the methyl and nitro substituents direct the incoming substituent to these positions
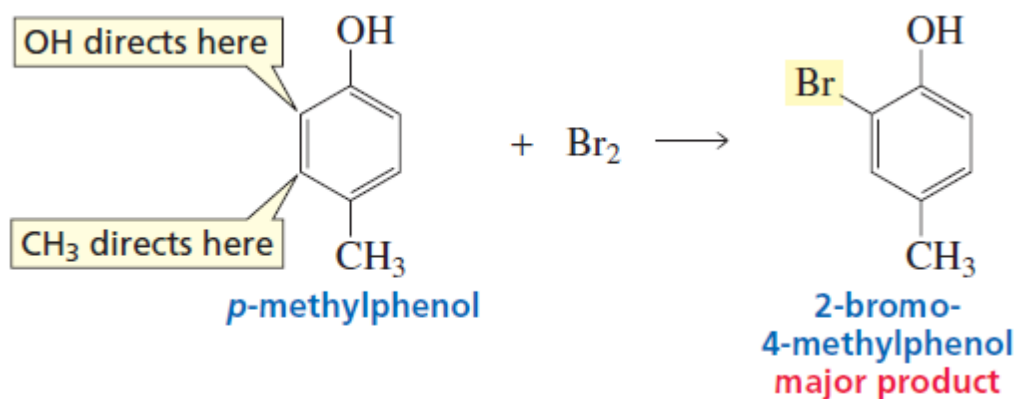
p-nitrotoluene

2,4-dinitrotoluene
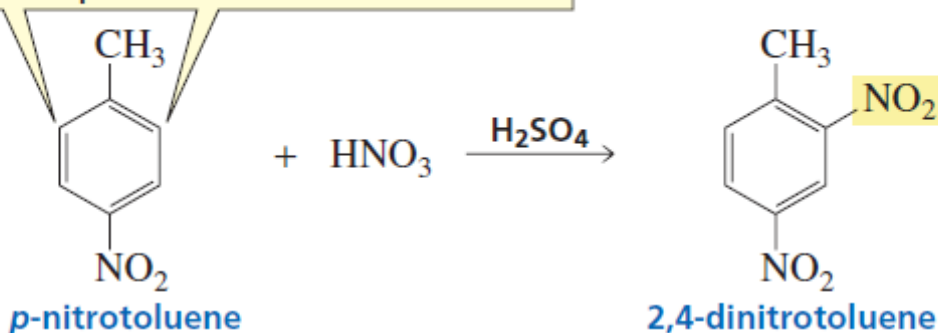
Notice that three positions are activated in the following reaction, but the new substituent ends up on only two of the three positions. Steric hindrance makes the position between the substituents less accessible.
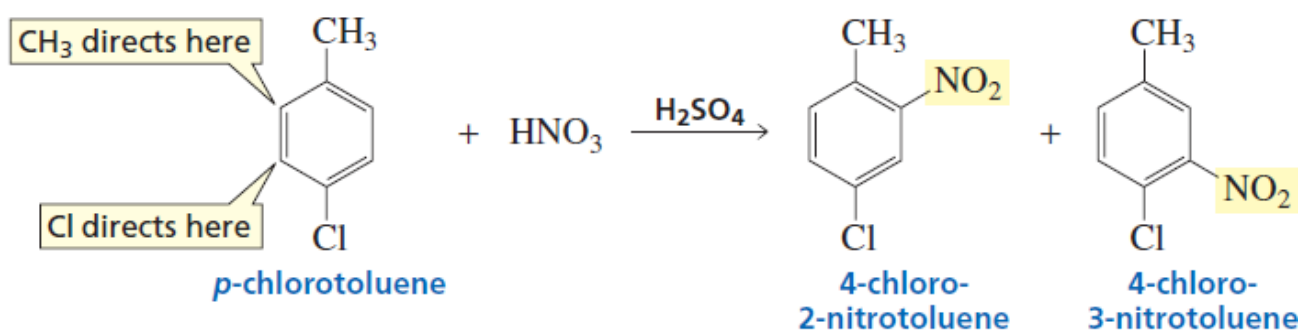

both the methyl and chloro substituents direct the incoming substituent to these indicated positions

m-chlorotoluene
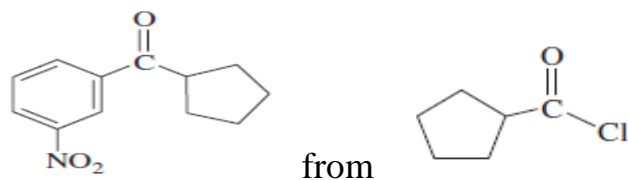
5-chloro-2-nitrotoluene

3-chloro-4-nitrotoluene
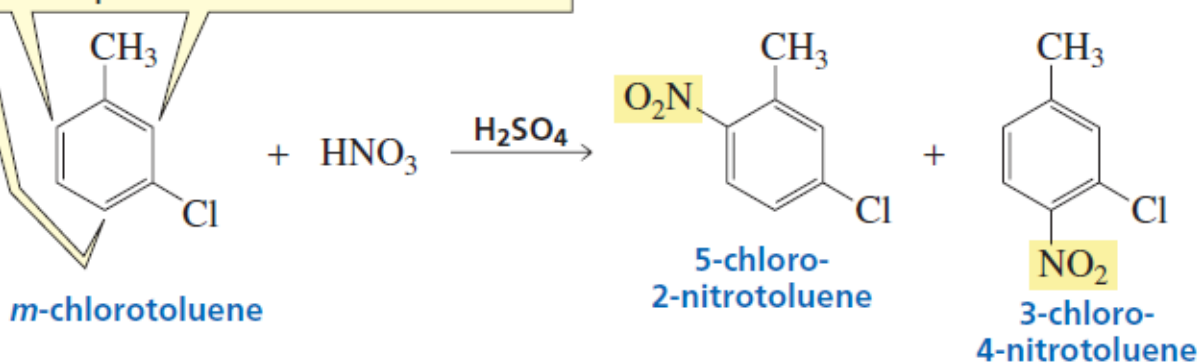
If the two substituents direct the new substituent to different positions, a strongly activating substituent will win out over a weakly activating substituent or a deactivating substituent.

20

OH directs here OH

+ Br₂ ⟶

CH₃ directs here CH₃

p-methylphenol

OH

Br

CH₃

2-bromo-
4-methylphenol
major product

If the two substituents have similar activating properties, neither will dominate and a mixture of products will be obtained.

CH₃ directs here CH₃

+ HNO₃ $\xrightarrow{H_2SO_4}$

Cl directs here Cl

p-chlorotoluene

CH₃
NO₂

Cl

4-chloro-
2-nitrotoluene

+

CH₃

NO₂

Cl

4-chloro-
3-nitrotoluene

Q/ How could you prepare the following compound?

from

Q/
Predict the major products of bromination of the following compounds, using Br₂ and FeBr₃ in the dark.

(a) (b) (c)