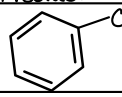
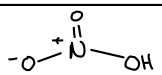
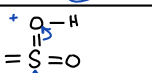
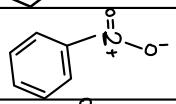
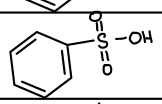
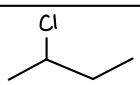
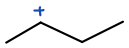
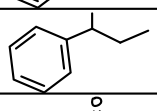
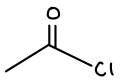
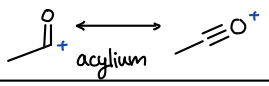
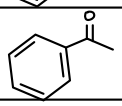
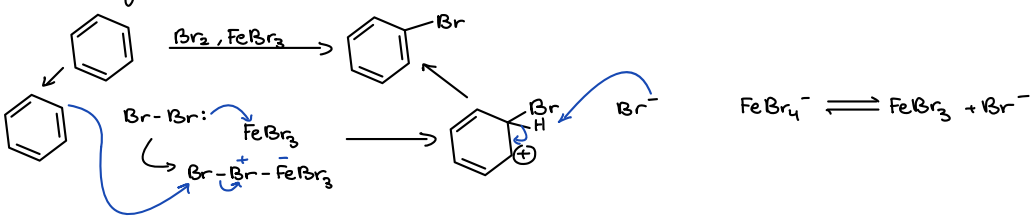
Benzene General Reactions Table

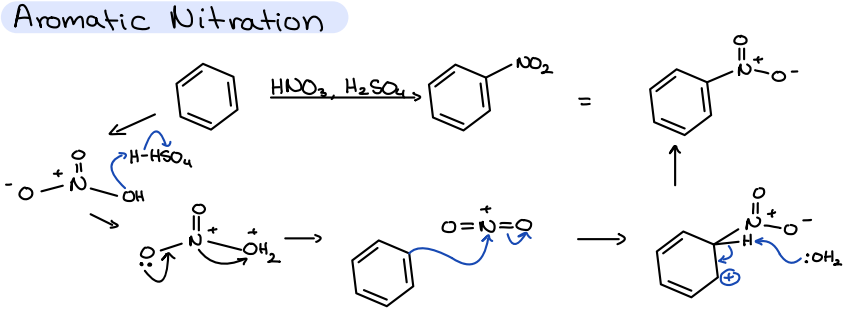
Reagent	Catalyst	Active Electrophile	Product
Cl_2	$FeCl_3$	$Cl\text{-}Cl\text{-}FeCl_3$	
HNO_3 	H_2SO_4		
SO_3 	H_2SO_4		
	$AlCl_3$		
	$AlCl_3$		

Aromatic Halogenation

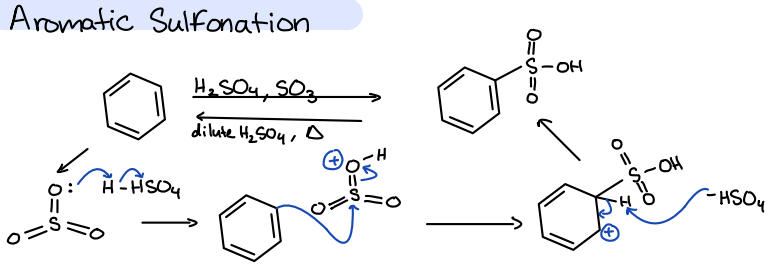


$FeBr_4^- \rightleftharpoons FeBr_3 + Br^-$

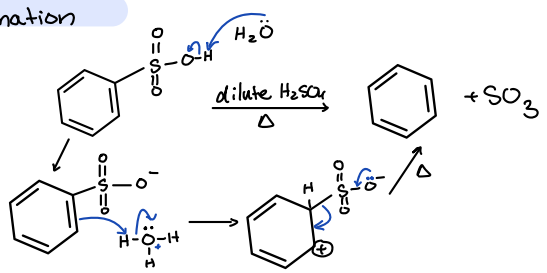
Aromatic Nitration



Aromatic Sulfonation

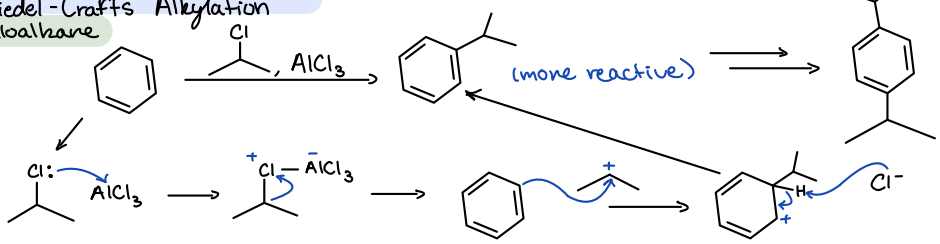


Desulfonation



Friedel-Crafts Alkylation

Haloalkane



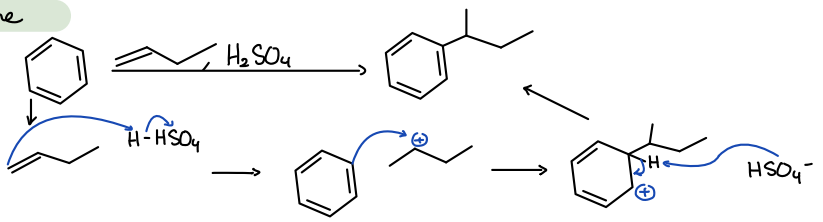
(if want leg. must be a less reactive starting material)

$AlCl_4^- \rightleftharpoons AlCl_3 + Cl^-$

↑ rate of rxn of benzene
- alkyl groups

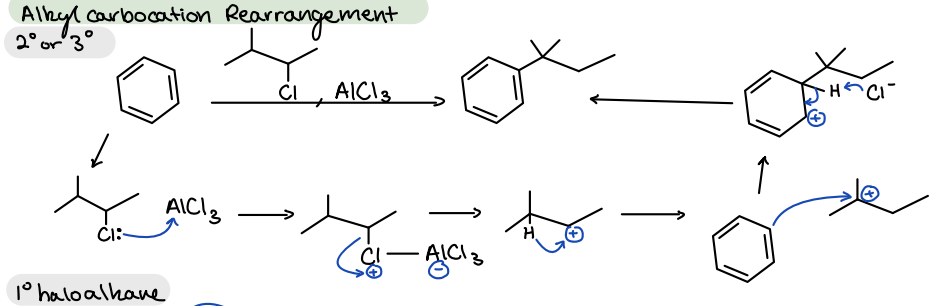
↓ rate of rxn of benzene
- halogens, nitryls, sulfonates (easy to add leg.)

Alkene

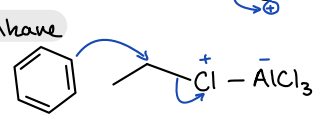


Alkyl carbocation Rearrangement

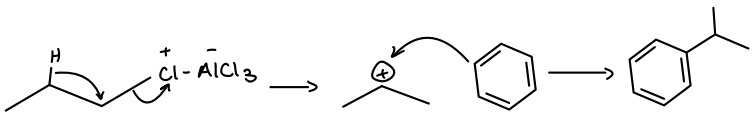
2° or 3°



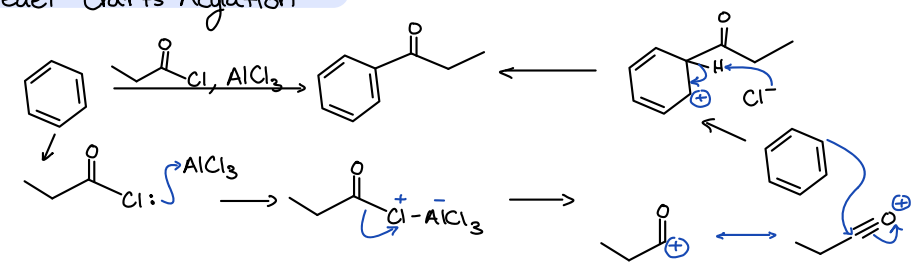
1° haloalkane



* Hydride shift as Cl leaves never get 1° C⁺



Friedel-Crafts Acylation



1) No carbocation rearrangements

2) Acyl groups make benzene less reactive (no multiple acylations)

3) use full eq. of LA. Aq. workup removes LA from C=O

Substituting Benzenes

1) Look at Resonance
- N or O w/ lone pair — EDG
- Polar pi bond - EWG

2) No resonance or poor resonance (X) at induction
- alkyl - e⁻ donor
- CF_3 - e⁻ acceptor

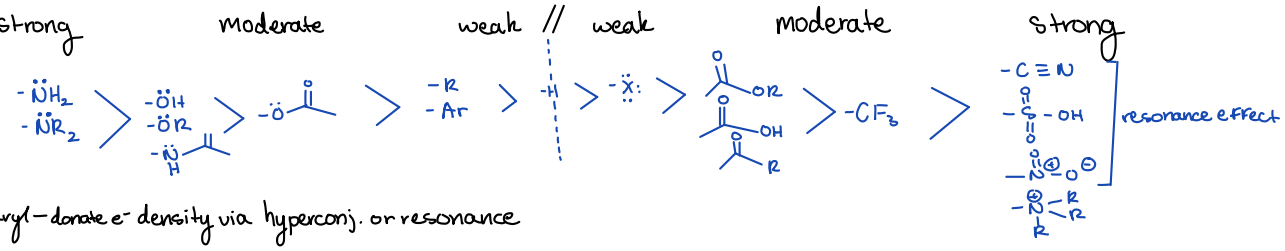
e⁻ donating groups = more e⁻ rich ring = more reactive as a Nu⁻

e⁻ withdrawing group = pulls e⁻ density out of the ring = weaker Nu⁻, slows down rxn

← e⁻ donating

e⁻ withdrawing →

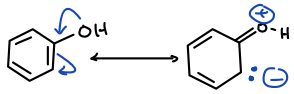
strong > moderate > weak // weak < moderate < strong



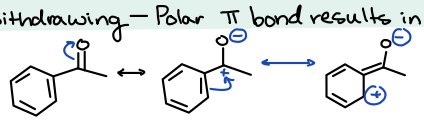
*alkyl and aryl - donate e⁻ density via hyperconj. or resonance

*carbonyls - pull delocalized e⁻ to itself so less available e⁻ density to donate into the ring

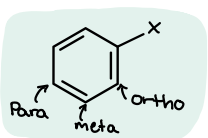
E⁻ Donors: resonance forms w/ (-) charge in ring



E⁻ withdrawing — Polar π bond results in resonance form w/ (+) charge in ring



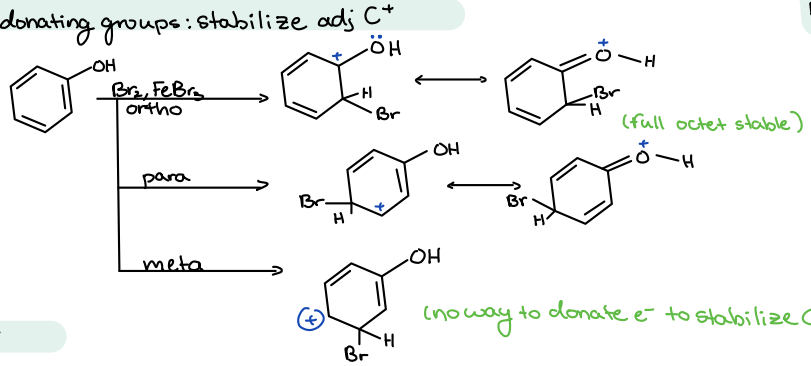
- ortho/para puts C⁺ directly next to directing group, meta addition does not



EDG/EWG in Regioselectivity

Group	Director
e⁻ donating	ortho/para
e⁻ withdrawing	meta
halogens	ortho/para

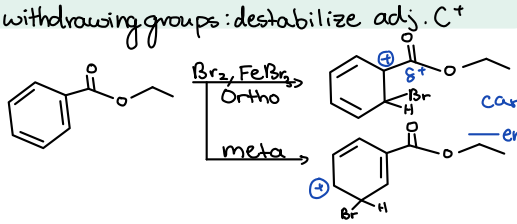
E⁻ donating groups: stabilize adj C⁺



(full octet stable)

(no way to donate e⁻ to stabilize C⁺)

e⁻ withdrawing groups: destabilize adj. C⁺



carbonyl w/ δ⁺ next to C⁺ — energetically disfavored

EDG ↑ rate at all positions but O/P more
EWG ↓ rate at all positions but O/P more

X group ↑ rate → favor O/P
X group ↓ rate → disfavor O/P

* when you have O/P directors assume you can selectively form the Para prod.
- Don't assume you can selectively form the ortho prod.

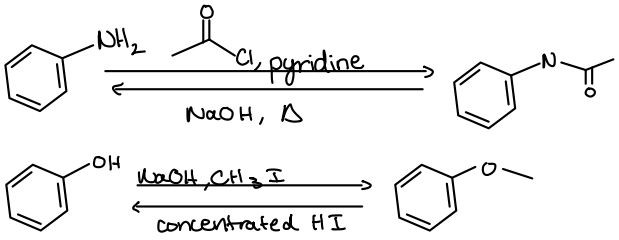
Multiple Directing Groups

- Strongest activator wins if conflict
- Substituents w/ same tier give rise to mixtures: $NR_2, OR > X, R >$ meta directors
- less sterically hindered spots are more likely to react — good selectivity if large diff b/t group sizes
  ↳ ignore additions b/t 2 substituents if other options available

Synthesis Limitations

- OH and NH_2 substituated benzenes can over-react and/or react themselves (strong activators — multiple additions)
- Friedel Craft Rxns don't work w/ moderately/strongly deactivated rings (strong EWG)
  ↳ no rxn if carbonyl or stronger deactivator and no activator
  ↳ no rxn w/ an alkene bc C^+ directly on alkene is too unstable

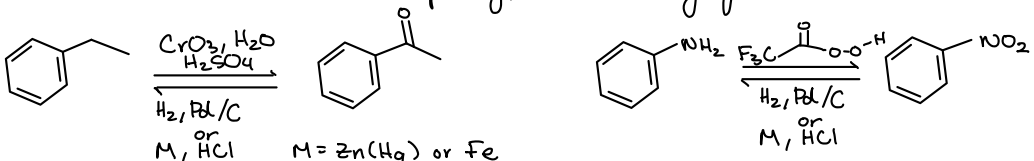
Moderating Reactivity of OH and NH_2



- lone pair shared w/ carbonyl — still ortho/para director but helps w/ overreaction or N acting as Nu⁻ instead of ring

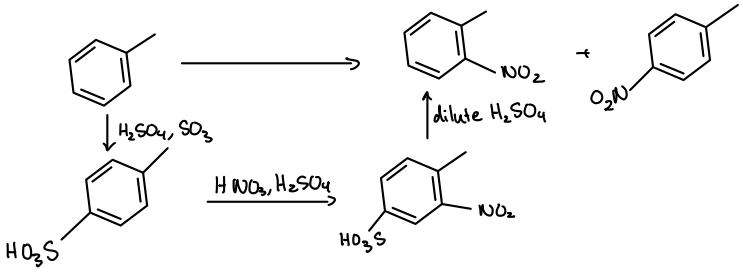
- deprotonate oxygen, SN2 on methyl iodide

Oxidations and Reductions to change type of directing group



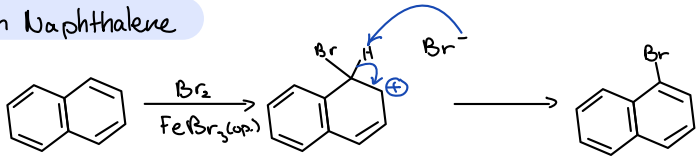
* Zn(Hg), HCl — clemmensen reduction

Sulfonation



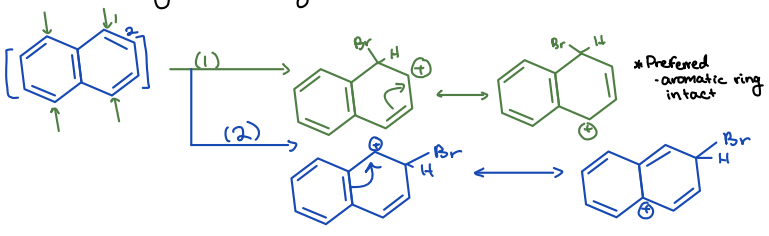
* temporarily block para-position

EAS on Naphthalene



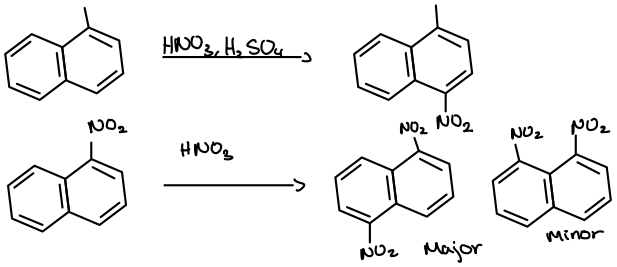
* Electrophilic aromatic substitution
* Naphthalene more reactive than benzene
  - only loses some of its aromaticity not all

Aromatic Regioselectivity

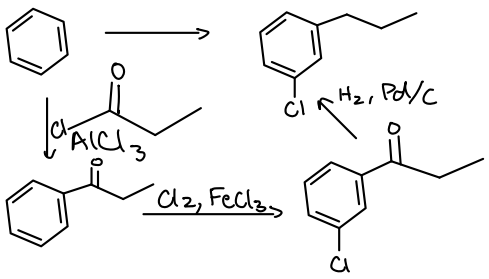


* Preferred - aromatic ring intact

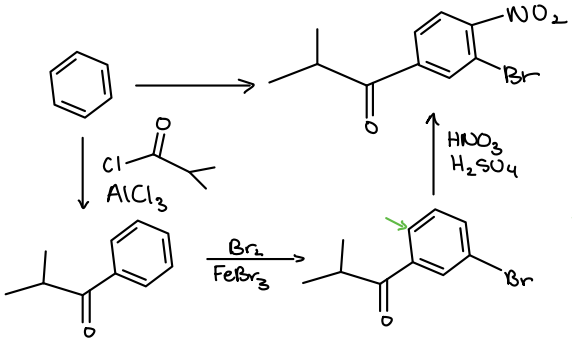
Multiple Groups



Synthesis Examples

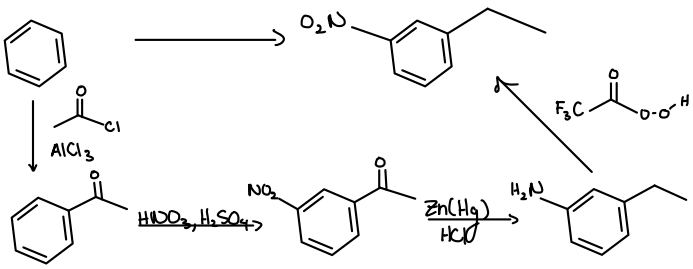


* 2 groups — both O/P directors in meta orientation



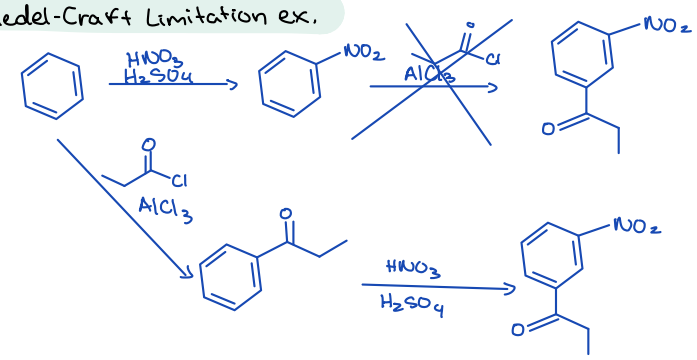
- para position hindered by carbonyl group

* Br : stronger activator directs ortho/para



* Jones also reduces NO_2

Friedel-Craft Limitation ex.



- Nitrobenzene not strong enough Nu^- to react w/ C^+ or acyliums