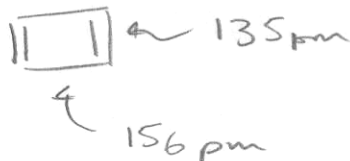


1. What are the four requirements (conditions) for being "aromatic?" (8 points)

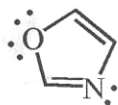
- cyclic system
- planar
- fully conjugated (-all  $sp^2$ )
- $4n+2$   $e^-$  in  $\pi$  system (Hückel's rule)

2. Where benzene ( $C_6H_6$ ) has only one carbon-carbon bond length (140 pm), cyclobutadiene ( $C_4H_4$ ) has two different carbon-carbon bond lengths (135 and 156 pm). Clearly explain why. (5 points)



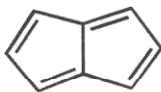
cyclobutadiene is a  $4n$  case, which is anti-aromatic - to avoid being anti-aromatic it distorts geometry.

3. For each of the following molecules or ions indicate whether they are aromatic, anti-aromatic or non-aromatic. (16 points)



oxazole

aromatic



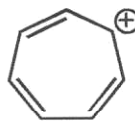
pentalene

anti-aromatic



cyclopentadiene

non-aromatic

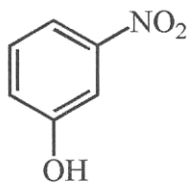


cycloheptatrienyl cation

aromatic

4. Provide IUPAC names (not common!) for the following compounds. (10 points)

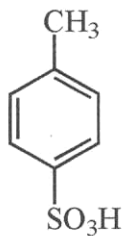
a.



3-nitrophenol

(m-nitrophenol is common!)

b.



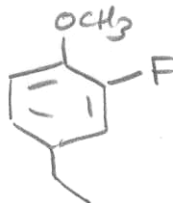
4-methyl benzenesulfonic acid

(p-toluene sulfonic acid is common!)

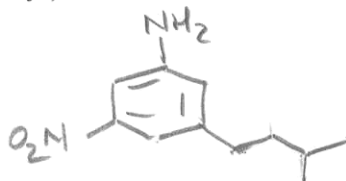
5. Draw the structure of the following compounds.

(10 points)

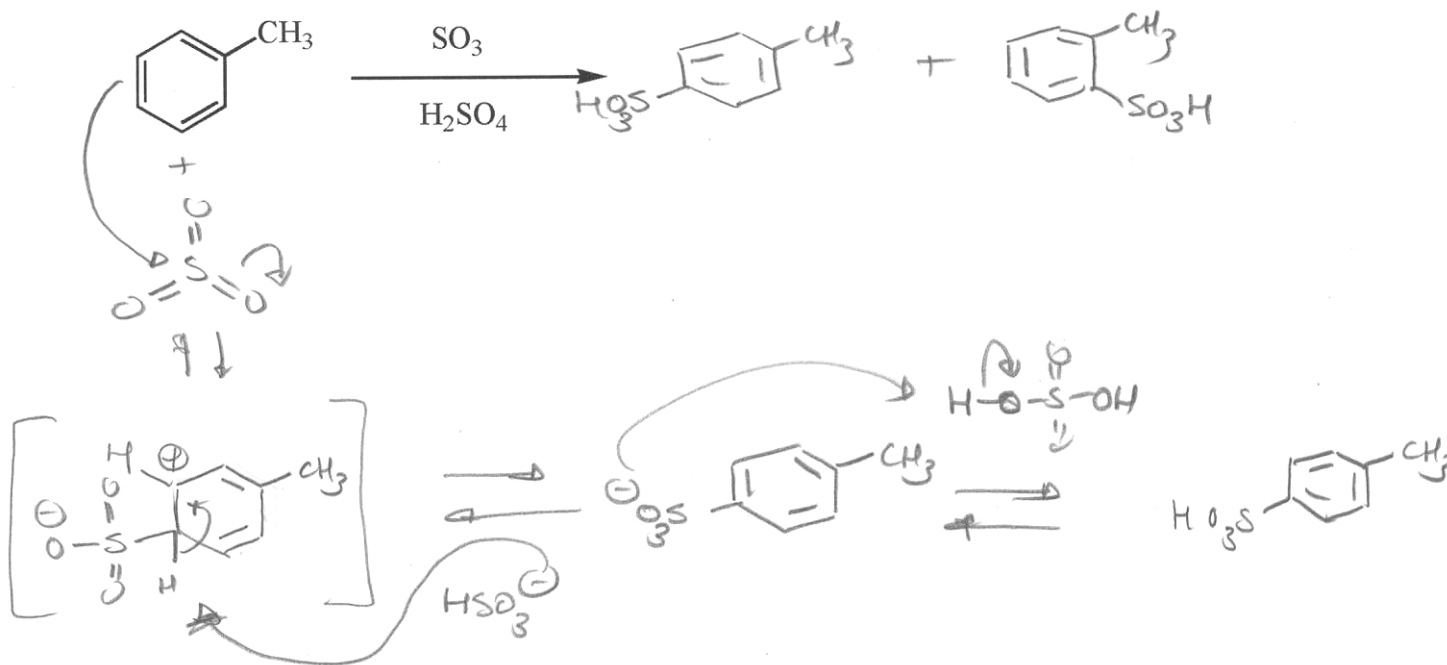
a. 4-ethyl-2-fluoroanisole



b. 3-(3-methylbutyl)-5-nitroaniline

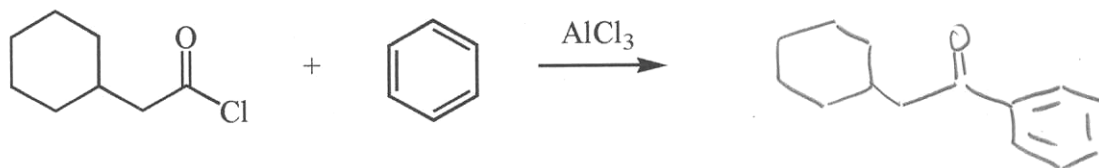


6. Show the product (or products) and the complete mechanism (with electron-pushing) for the following reaction. (if more than one isomer is formed show the mechanism for only one of them, but be sure show all expected products) (15 points)

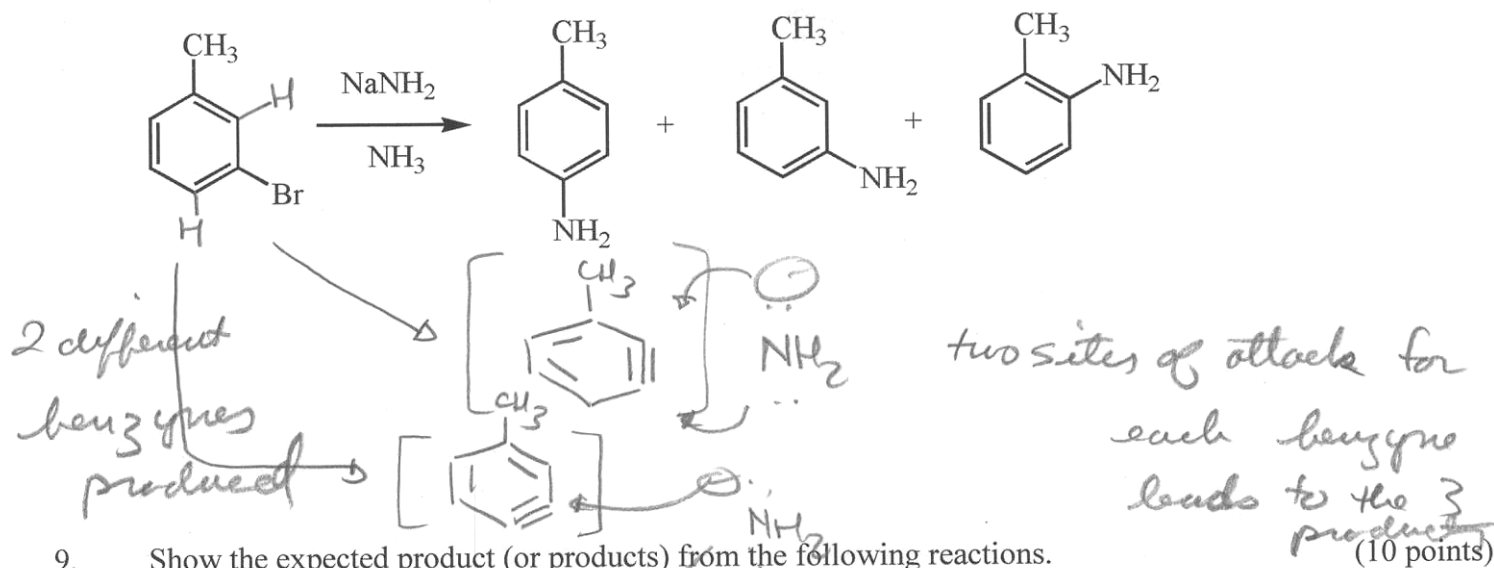


7. Show the product (or products) from the following Friedel-Crafts acylation.

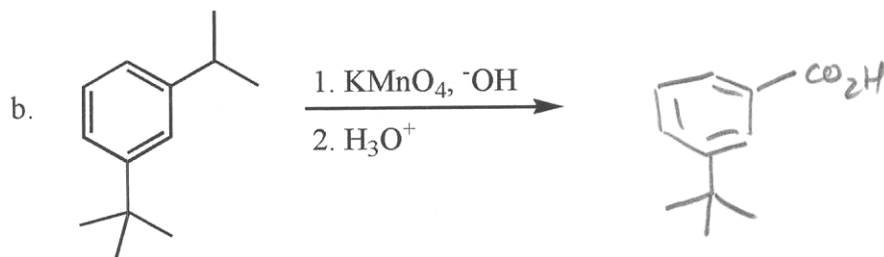
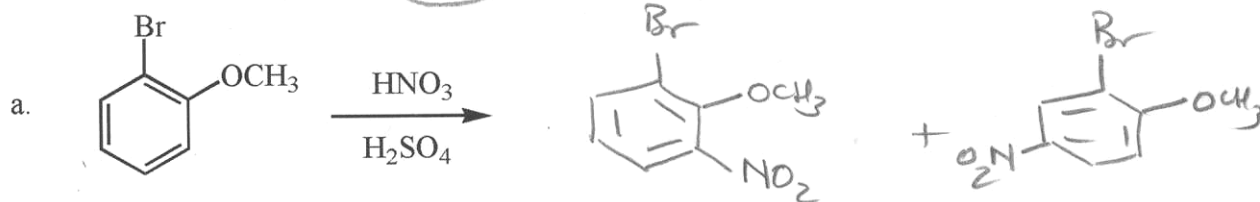
(5 points)



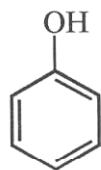
8. Explain in terms of the mechanism of the reaction why the reaction below produces the three products shown in roughly equal amounts. (10 points)



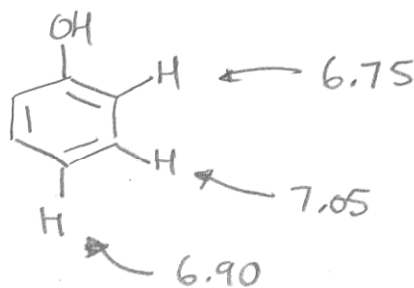
9. Show the expected product (or products) from the following reactions. (10 points)



10. Use the included NMR data sheet to estimate the chemical shift of the aromatic hydrogens (o, m, and p) in phenol (PhOH). Explain how the chemical shift data indicate whether the aromatic substituent is an ortho/para director or a meta director in an Electrophilic Aromatic Substitution reaction. (15 points)

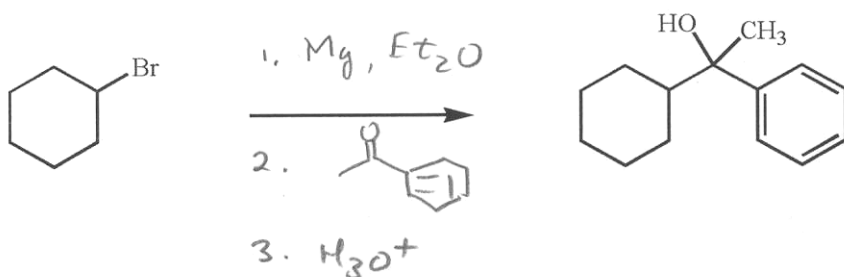


phenol

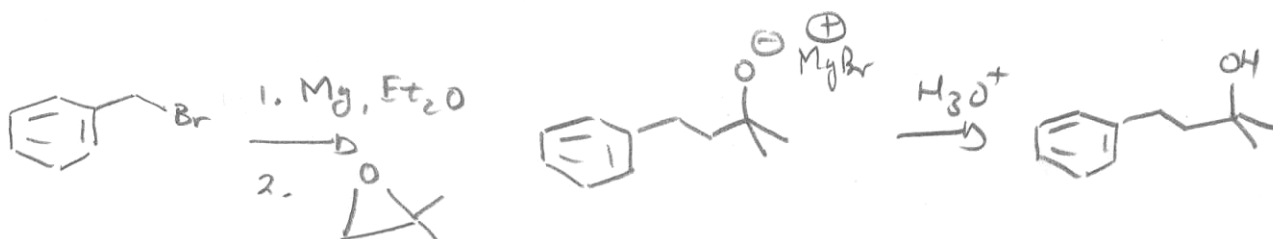
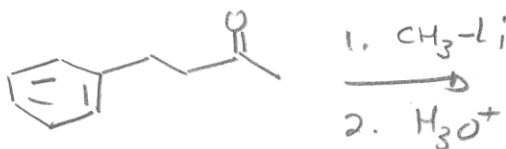
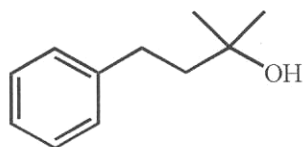


lower chemical shift means greater shielding and in this case greater shielding, so the ortho/para positions are more electron-rich and more reactive - ortho/para directing

11. Show the reagents and conditions (over and under the arrow) that are needed to accomplish the following reaction. (10 points)



12. Show two (2) syntheses for the following compound, both of which utilize organometallic compounds and one of which utilizes an epoxide. (10 points)



13. EXTRA CREDIT - Challenge. Suggest a structure for B, which is aromatic. (5 EC points)

