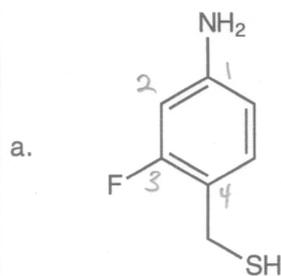
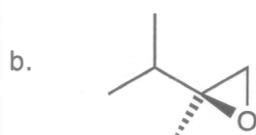


1. Provide IUPAC names for the following compounds.

(20 points)



2-fluoro-4-(mercaptomethyl)aniline



(S)-1,2-epoxy-2,3-dimethylbutane

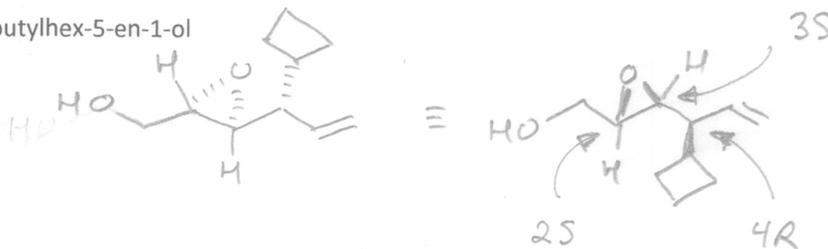
or

(S)-2-isopropyl-2-methyloxirane

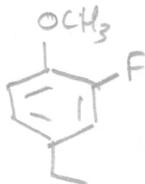
2. Provide structures for the following compounds.

(30 points)

a. (2S,3S,4R)-2,3-epoxy-4-cyclobutylhex-5-en-1-ol



b. 4-ethyl-2-fluoroanisole

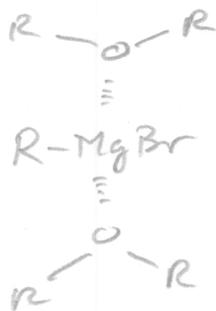


c. cyclohexene oxide



3. Explain why ether solvents, such as Et<sub>2</sub>O and THF, are required to perform Grignard reactions.

(5 points)

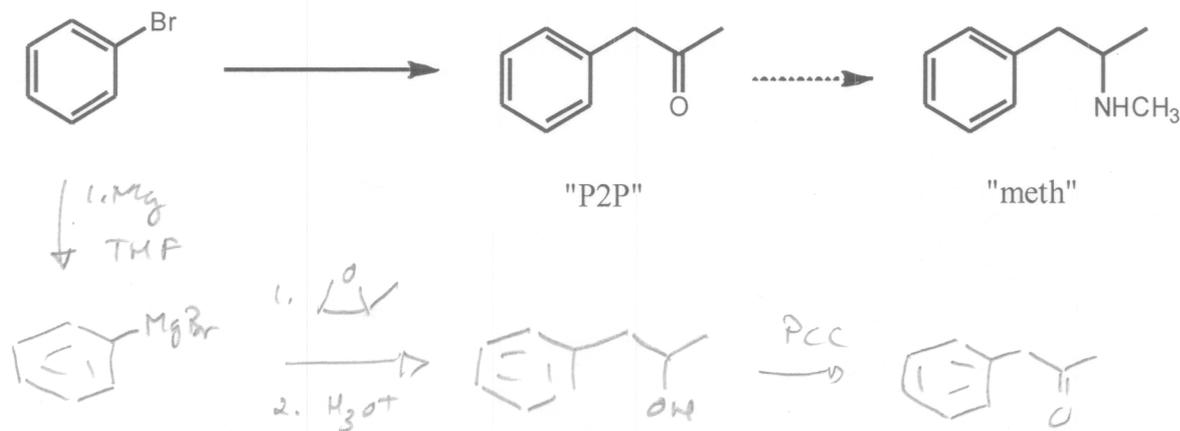


The ether oxygen acts as a Lewis base and stabilizes the magnesium and allows the Grignard reagent to form and stay in solution.

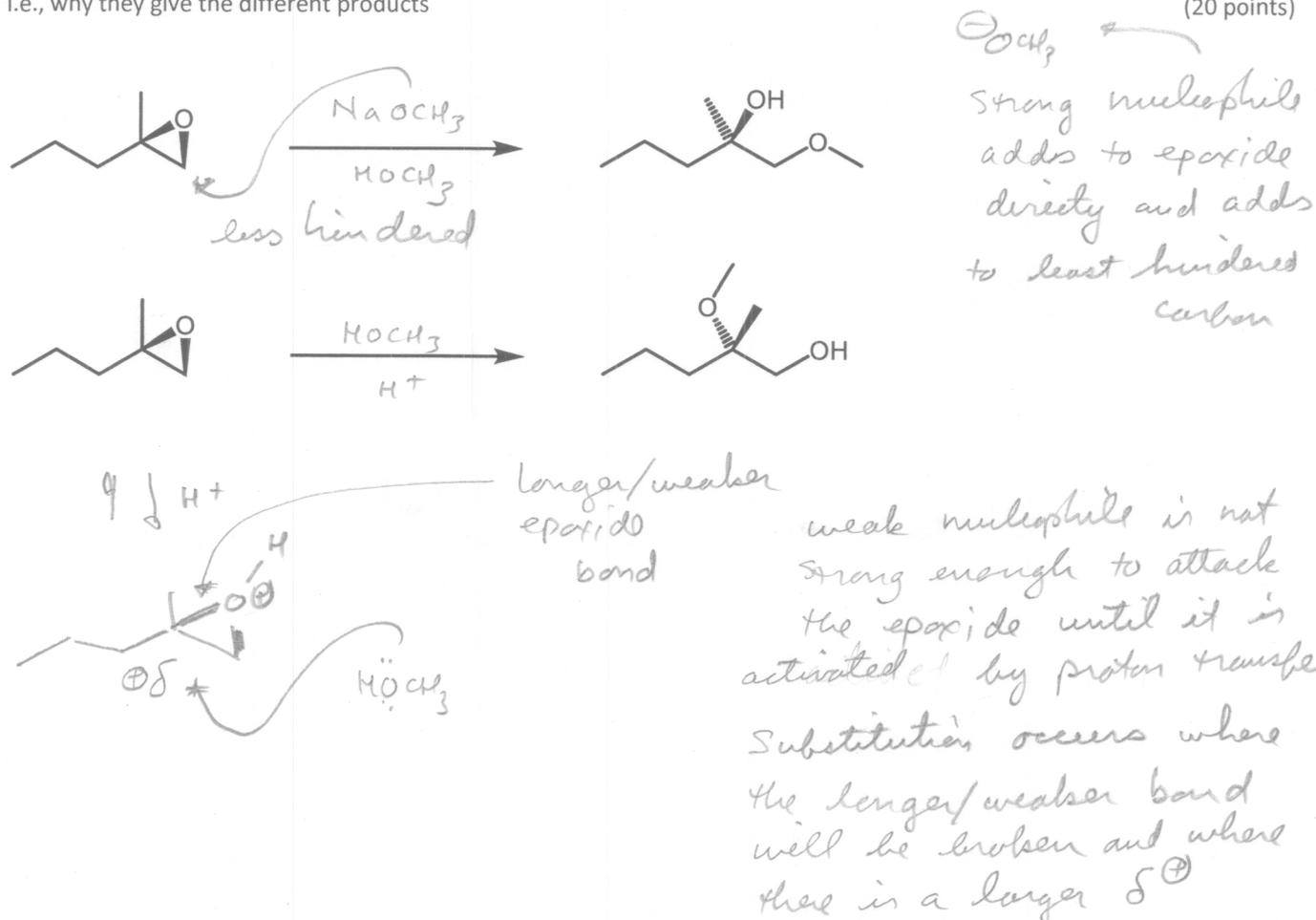
Also, ethers are aprotic solvents - protic solvents can not be used in Grignard reactions because they react (deprotonate) with them.

4. The ketone shown below, "P2P," is an infamous starting material for the street drug methylamphetamine ("meth"). Show how to convert bromobenzene into this ketone using any reagents that you want, but must include an epoxide at some point. Show all intermediates.

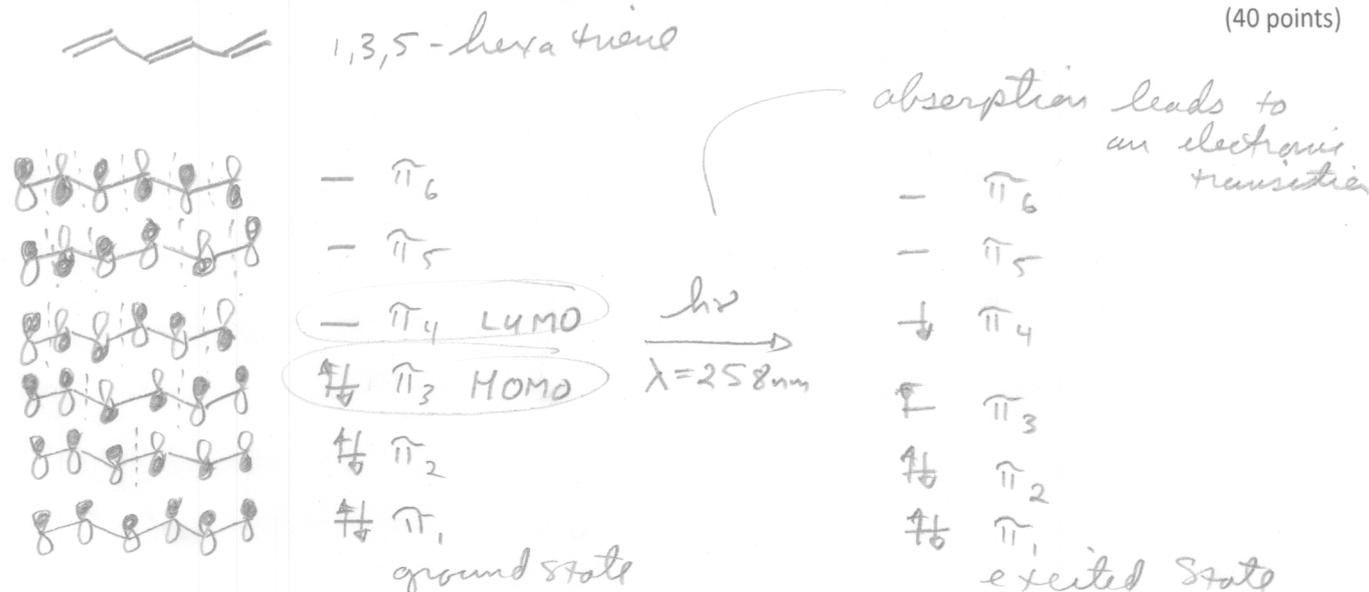
(20 points)



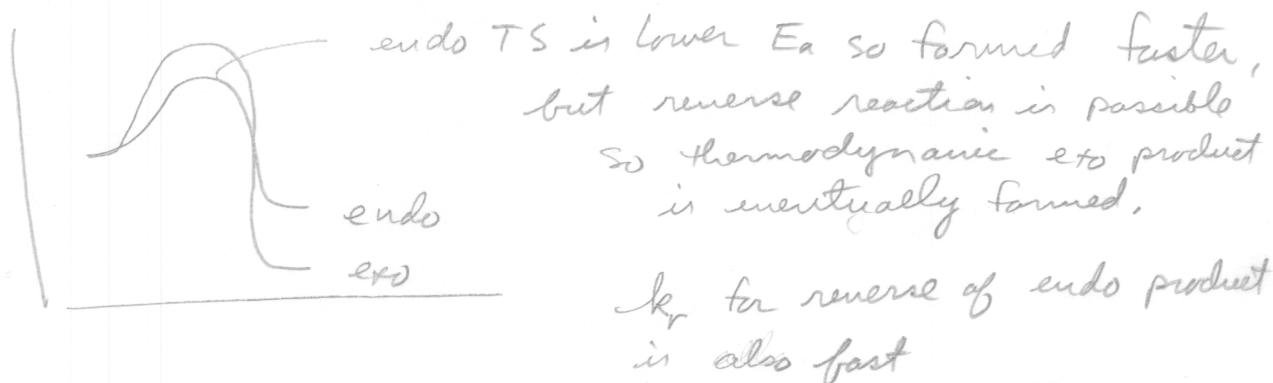
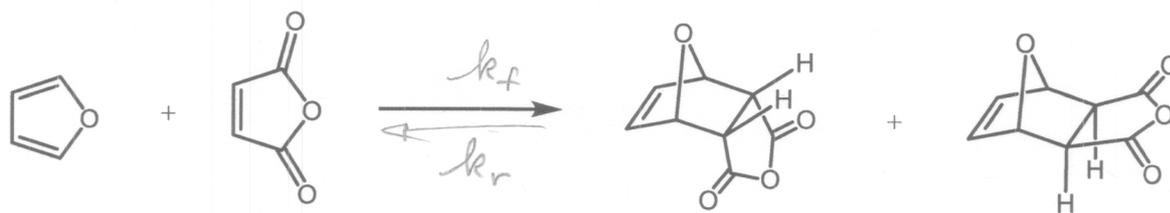
5. Show the reagents necessary to accomplish the two transformations. Explain your reasoning behind the choice of reagents, i.e., why they give the different products (20 points)



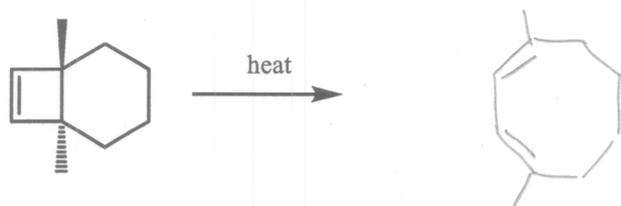
6. Draw the pi molecular orbitals of 1,3,5-hexatriene and their relative energy levels. Show how these orbitals are filled with electrons in the ground state. Indicate which orbital is the Highest Occupied MO (HOMO) and which is the Lowest Unoccupied MO (LUMO). Finally, describe what happens when 1,3,5-hexatriene absorbs in the UV region at 258 nm. (40 points)



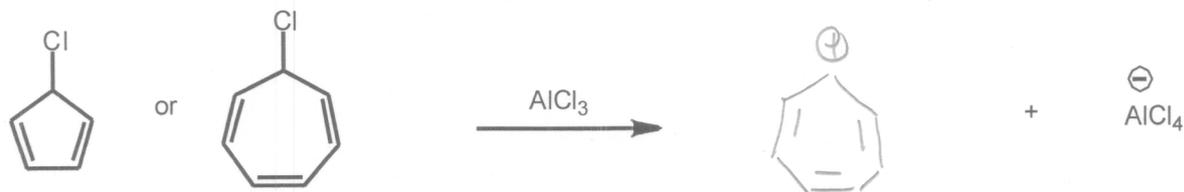
7. The Diels-Alder reaction shown below gives only the *exo* addition product as the only isolated product. Which product shown below is the *exo* product? Considering the *thermodynamics* and *kinetics* of this reaction, and using an energy diagram, explain how and why the *endo* rule is "violated" in this case. (20 points)



8. Show the product from the following *pericyclic* reaction. Clearly show the stereochemistry of the product. (10 points)



9. One of the two compounds below reacts with aluminum chloride and the other one doesn't. Show the intermediate formed from the one that does and explain why the other one doesn't. (10 points)



doesn't

form since it would be anti-aromatic

tropylium ion

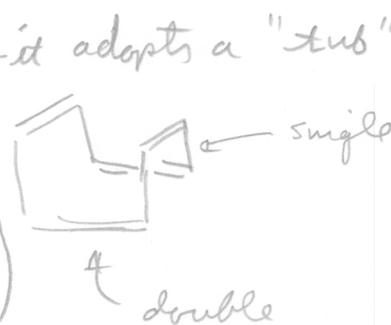
- very stable due to being aromatic -  $4n+2e^-$  in cyclic conjugated system

10. Unlike benzene, 1,3,5,7-cyclooctatetraene has two different carbon-carbon bond lengths, 1.33 Å and 1.46 Å and it is definitely not planar. Clearly explain why (draw pictures if necessary). (10 points)

Extra Credit. Suggest an alternate name for this compound. (5 EC points)



Since this molecule would be anti-aromatic if flat,

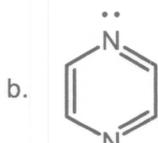


it adopts a "tub" shape, which minimizes the overlap between adjacent  $\pi$  bonds - so it has alternating single and double bond lengths.

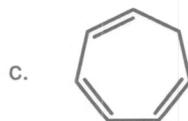
11. For each of the following molecules or ions indicate whether they are aromatic, anti-aromatic or non-aromatic. (20 points)



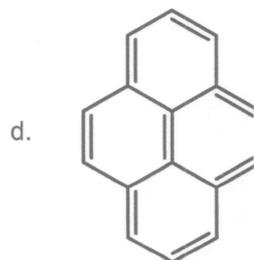
aromatic



aromatic

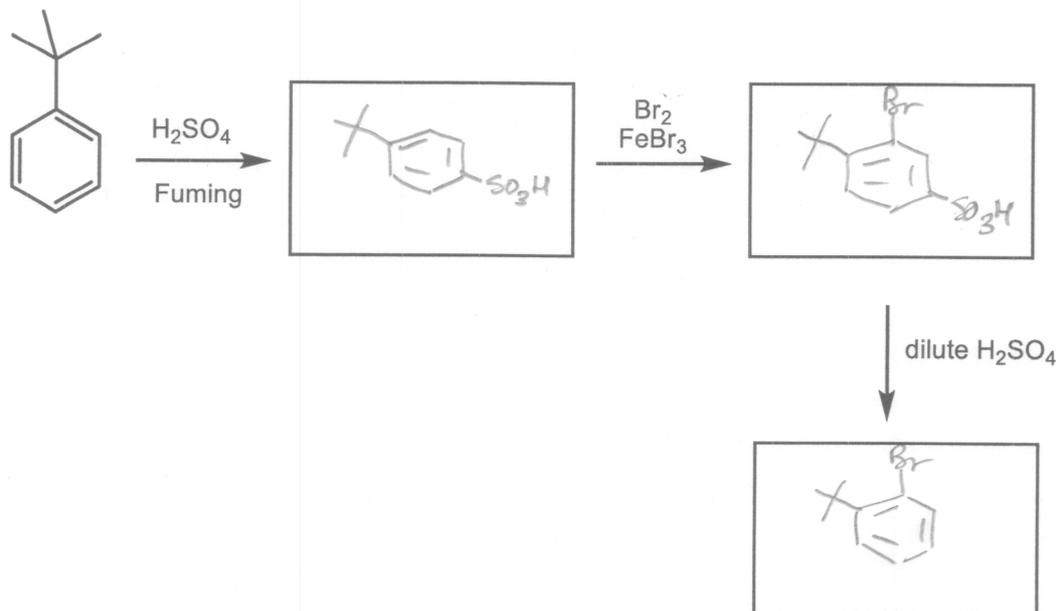


non-aromatic

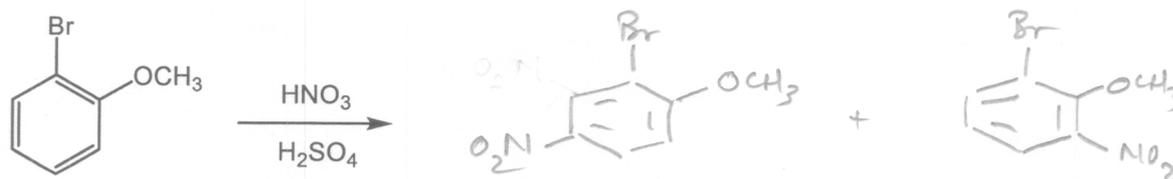


aromatic

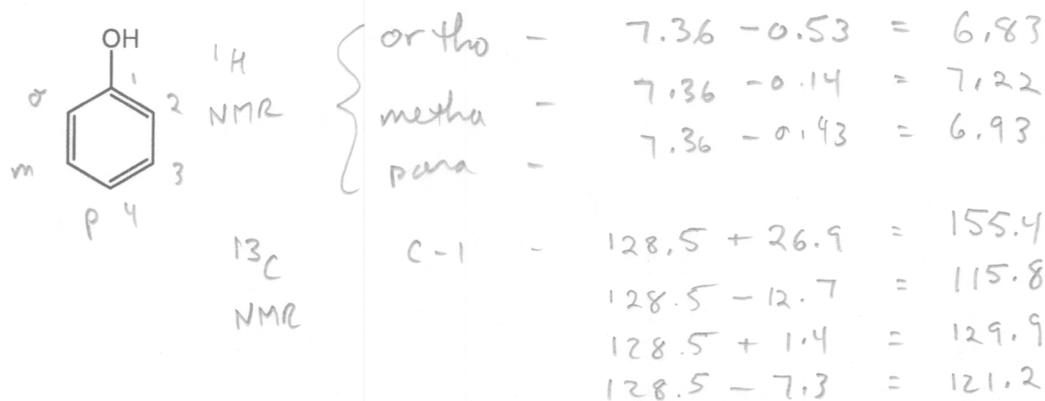
12. In the following synthesis, fill in the products or reagents. (15 points)



13. Show the expected product (or products) from the following reaction. (10 points)



14. Use the NMR data sheets (from lecture) to calculate the proton and carbon NMR chemical shifts for phenol. Explain how the chemical shift data indicate whether the aromatic substituent is an *activating* or *deactivating* group and whether it is an *ortho/para* director or a *meta* director in an Electrophilic Aromatic Substitution reaction ( $S_EAr$ ). (20 points)

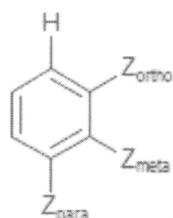


Both  $^1\text{H}$  &  $^{13}\text{C}$  chemical shifts for the ortho & para positions are shielded relative to benzene, so these positions are more electron rich and thus more reactive in the  $S_EAr$  reaction, so  $-\text{OH}$  is an activating group and an ortho/para director.

Tables from:

<http://www.chem.wisc.edu/areas/reich/chem605/index.htm>

Benzene Substituent Effects for  $^1\text{H}$  NMR



$$\delta_{\text{Ar-H}} = 7.36 + Z_{\text{ortho}} + Z_{\text{meta}} + Z_{\text{para}}$$

Substituent R	Z <sub>ortho</sub>	Z <sub>meta</sub>	Z <sub>para</sub>		Substituent R	Z <sub>ortho</sub>	Z <sub>meta</sub>	Z <sub>para</sub>
H	0.0	0.0	0.0		OH <sup>a</sup>	-0.53	-0.14	-0.43
CH <sub>3</sub> <sup>a</sup>	-0.18	-0.11	-0.21		OCH <sub>3</sub> <sup>a</sup>	-0.45	-0.07	-0.41
C(CH <sub>3</sub> ) <sub>3</sub>	0.02	-0.08	-0.21		OPh <sup>a</sup>	-0.36	-0.04	-0.28
o-Propyl	-0.33	-0.15	-0.26	SDBS	O-C(O)CH <sub>3</sub> <sup>a</sup>	-0.27	-0.02	-0.13
CH <sub>2</sub> Cl	0.02	-0.01	-0.04		O-C(O)Ph <sup>a</sup>	-0.14	0.07	-0.09
CH <sub>2</sub> OH	-0.07	-0.07	-0.07		O-SO <sub>2</sub> Me	-0.05	0.07	-0.01
CF <sub>3</sub>	0.32	0.14	0.20		SH	-0.08	-0.16	-0.22
CCl <sub>3</sub>	0.64	0.13	0.10		SMe	-0.08	-0.10	-0.24
CH=CH <sub>2</sub>	0.04	-0.04	-0.12		SPh	0.06	-0.09	-0.15
CH=CHCOOH <sup>a</sup>	0.19	0.04	0.05		SO <sub>2</sub> Cl	0.76	0.35	0.45
C≡C-H	0.15	-0.02	-0.01		NH <sub>2</sub> <sup>a</sup>	-0.71	-0.22	-0.62
C≡C-Ph <sup>a</sup>	0.17	-0.02	-0.03		NMe <sub>2</sub>	-0.66	-0.18	-0.67
Ph <sup>a</sup>	0.23	0.07	-0.02		NEt <sub>2</sub> <sup>a</sup>	-0.68	-0.15	-0.73
COOH <sup>a</sup>	0.77	0.11	-0.25		NMe <sub>3</sub> <sup>+</sup>	0.69	0.36	0.31
C(O)OCH <sub>3</sub> <sup>a</sup>	0.68	0.08	0.19		NHC(O)CH <sub>3</sub> <sup>a</sup>	0.14	-0.07	-0.27
C(O)OPh <sup>a</sup>	0.85	0.14	0.27		NH-NH <sub>2</sub>	-0.60	-0.08	-0.55
C(O)NH <sub>2</sub> <sup>a</sup>	0.46	0.09	0.17		N=N-Ph	0.67	0.20	0.20
C(O)Cl <sup>a</sup>	0.76	0.16	0.33		N=O	0.58	0.31	0.37
C(O)CH <sub>3</sub> <sup>a</sup>	0.60	0.10	0.20		NO <sub>2</sub> <sup>a</sup>	0.87	0.20	0.35
C(O)C(CH <sub>3</sub> ) <sub>3</sub>	0.44	0.05	0.05		P(O)(OMe) <sub>2</sub>	0.48	0.16	0.24
C(O)H <sup>a</sup>	0.53	0.18	0.28		SiMe <sub>3</sub>	0.22	-0.02	-0.02
C(NPh)H	0.6	0.2	0.2					
C(O)Ph <sup>a</sup>	0.45	0.12	0.23					
C(O)C(O)Ph <sup>a</sup>	0.62	0.15	0.30					
C≡O <sup>+</sup>	1.54	0.96	1.40	JA-69-5320				
CN <sup>a</sup>	0.29	0.12	0.25					
F	-0.29	-0.02	-0.23					
Cl <sup>a</sup>	-0.02	-0.07	-0.13					
Br <sup>a</sup>	0.13	-0.13	-0.08					
I	0.39	-0.21	0.00					
I-Ph <sup>+</sup> Cl <sup>-</sup>	0.63	-0.01	0.15					

<sup>a</sup> Data in dilute CDCl<sub>3</sub> by Paul Schatz, University of Wisconsin, Madison. Original data from *J. Am. Chem. Soc.* 1956, 78, 3043 at 30 MHz with 50% solutions in cyclohexane.

Benzene Substituent for  $^{13}\text{C}$  NMR

Benzene(=128.5)				
X	C1	C2	C3	C4
F-	34.8	-12.9	1.4	-4.5
Cl-	6.2	0.4	1.3	-1.9
Br-	-5.5	3.4	1.7	-1.6
I-	-34.1	8.7	1.4	-1.4
HO-	26.9	-12.7	1.4	-7.3
LiO-	40.5	-7.6	1.7	-14.2
MeO-	31.4	-14.4	1.0	-7.7
AcO-	19.3	-9.8	-2.2	-6.9
HS-	2.2	0.7	0.4	-3.1
MeS-	9.9	-2.0	0.1	-3.7
H <sub>2</sub> N-	18.0	-13.3	0.9	-9.8
Me <sub>2</sub> N-	22.6	-15.6	1.0	-11.5
AcNH-	11.1	-9.9	0.2	-5.6
H <sub>2</sub> N-NH-	22.8	-16.6	0.5	-9.6
CN-	-1.8	-2.2	1.4	0.9
O <sub>2</sub> N-	20.0	-4.8	0.9	5.8
ON-	37.4	-7.7	0.8	7.0
Ph <sub>2</sub> P-	8.7	5.1	-0.1	0.0
Me-	8.9	0.7	-0.1	-2.9
Et-	15.7	-0.6	-0.1	-2.8
iPr-	20.1	-2.0	0.0	-2.5
tBu-	22.1	-3.4	-0.4	-3.1
CF <sub>3</sub> -	2.6	-3.1	0.4	3.4
ClCH <sub>2</sub> -	9.1	0.0	0.2	-0.2
CH <sub>2</sub> =CH-	7.6	-1.8	-1.8	-3.5
HC≡C-	-6.1	3.8	0.4	-0.2
Ph-	13.0	-1.1	0.5	-1.0
MeO <sub>2</sub> C-	1.8	1.0	-0.2	5.3
Me(O)C-	9.1	0.1	0.0	4.2
H <sub>2</sub> N(O)C-	5.4	-0.3	-0.9	5.0
H(O)C-	8.6	1.3	0.6	5.5
HO <sub>2</sub> C-	2.4	1.6	-0.1	4.8
NC-	-15.4	3.6	0.6	3.9
Me <sub>3</sub> Si-	13.4	4.4	-1.1	-1.1
Li-	68.2	14.9	-3.7	-7.7