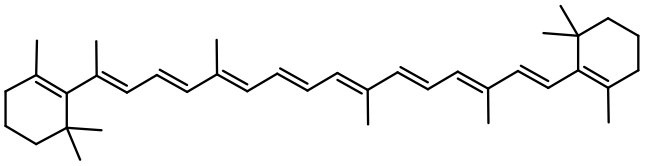
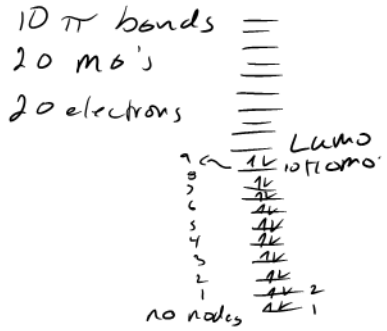
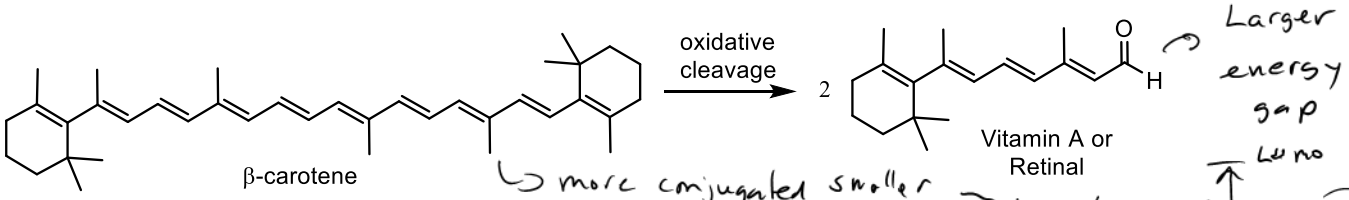
1) β-carotene is one of the pigments that causes carrots to look orange. How many nodes would the HOMO of β-carotene have?





A) 7 B) 9 C) 10 D) 19 E) 20

2) β -carotene is a precursor to vitamin A (Retinal) via the action of an enzyme called beta-carotene-15,15-monooxygenase. How does the energy gap between the HOMO-LUMO of vitamin A compare to β-carotene?



A) Energy gap between the HOMO-LUMO is larger for β-carotene
B) Energy gap between the HOMO-LUMO is larger for vitamin A
C) The energy gap would be the same

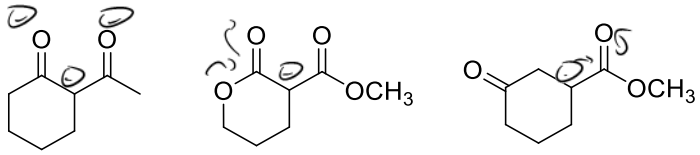
3) Purified and isolated β-carotene is actually a red-purple solid and vitamin A is an orange solid. Is vitamin A absorbing a longer or shorter wavelength of electromagnetic radiation.

A) Vitamin A is absorbing at a longer wavelength than β-carotene
B) Vitamin A is absorbing at a shorter wavelength than β-carotene

larger energy
higher frequency
shorter wavelength

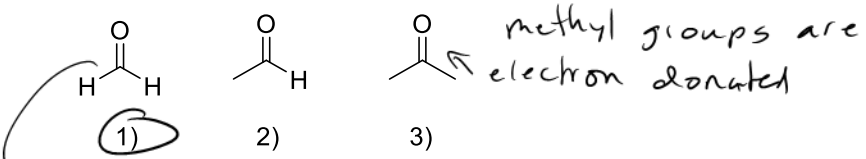
4) List the following acids form the strongest to the weakest.

A) 2 > 3 > 1
B) 3 > 2 > 1
C) 1 > 2 > 3
D) 2 > 1 > 3
E) 1 > 3 > 2
F) 3 > 1 > 2



1 > 2 > 3

5) Which of the following carbonyl compounds would be most reactive towards hydration?

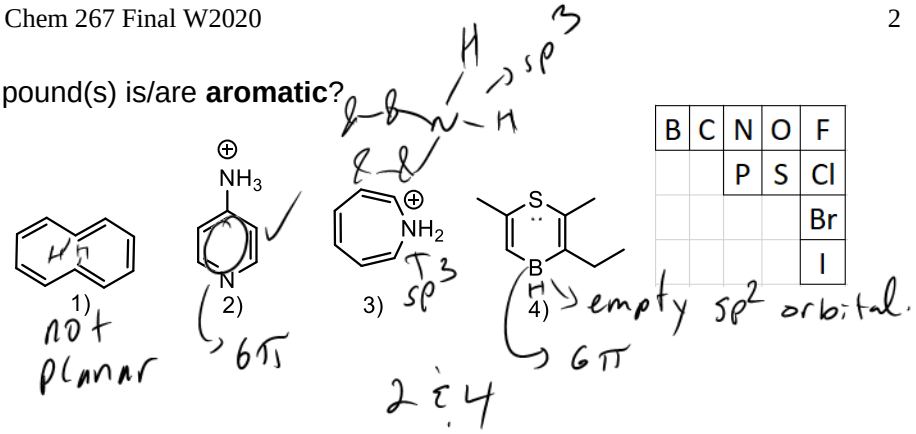


methyl groups are electron donated

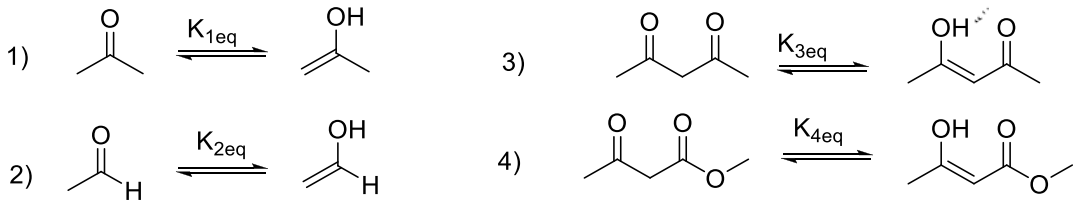
largest δ+ no steric hinderance
most reactive

6) Which of the following compound(s) is/are **aromatic**?

A) 1, 3 and 4
B) 1, 2 and 3
C) 2, 3 and 4
D) 2 and 4
E) Only 1
F) Only 4
G) All are aromatic



7) Order the equilibrium constants from largest to smallest? K_{eq} =[products]/[reactant]

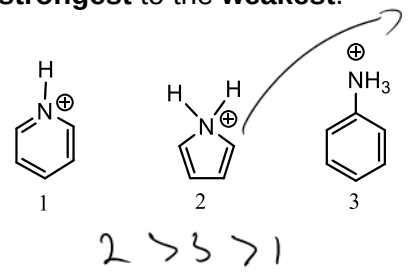


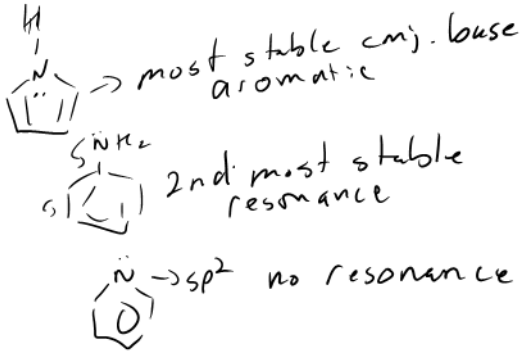
A) $K_{1eq} > K_{2eq} > K_{4eq} > K_{3eq}$
B) $K_{2eq} > K_{1eq} > K_{4eq} > K_{3eq}$
C) $K_{3eq} > K_{2eq} > K_{1eq} > K_{4eq}$
D) $K_{3eq} > K_{4eq} > K_{2eq} > K_{1eq}$
E) $K_{4eq} > K_{3eq} > K_{2eq} > K_{1eq}$

3 > 4 > 2 1

8) List the follow acids from the **strongest** to the **weakest**.

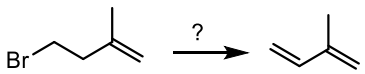
A) 1 > 2 > 3
B) 2 > 1 > 3
C) 3 > 2 > 1
D) 2 > 3 > 1
E) 1 > 3 > 2
F) 3 > 1 > 2



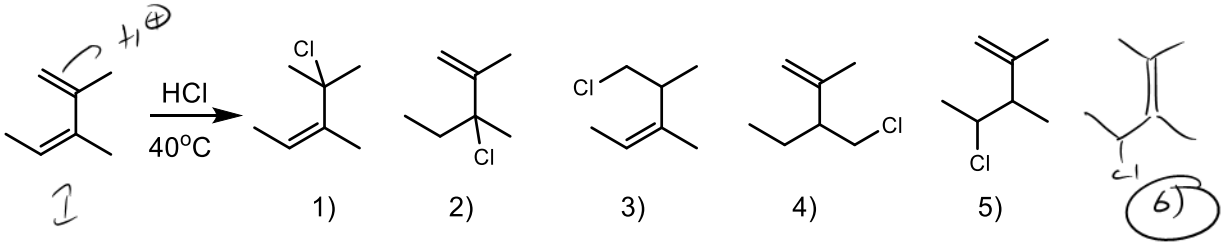


9) Which reagent would produce the diene in the greatest yield? (Note: Only reagents given not reaction conditions)

A) Conc. H_2SO_4
B) $NaOH/H_2O$
C) $KMnO_4$
D) LDA
E) H_2 / Pt
F) None of these

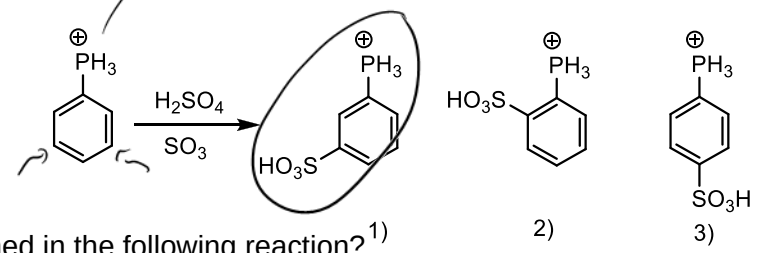


10) What is the major product produced in the following reaction?



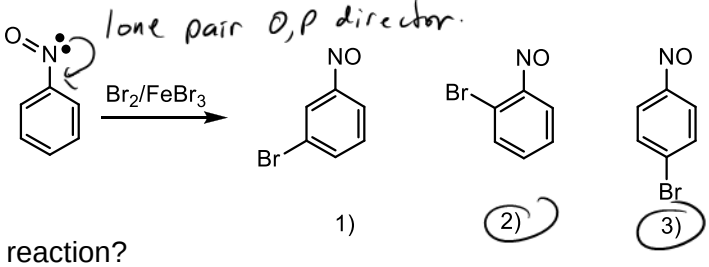
11) What is/are the **major** product(s) formed in the following reaction?

A) Only 1
B) Only 2
C) Only 3
D) Mixture of 2 and 3
E) All are formed in equal amounts

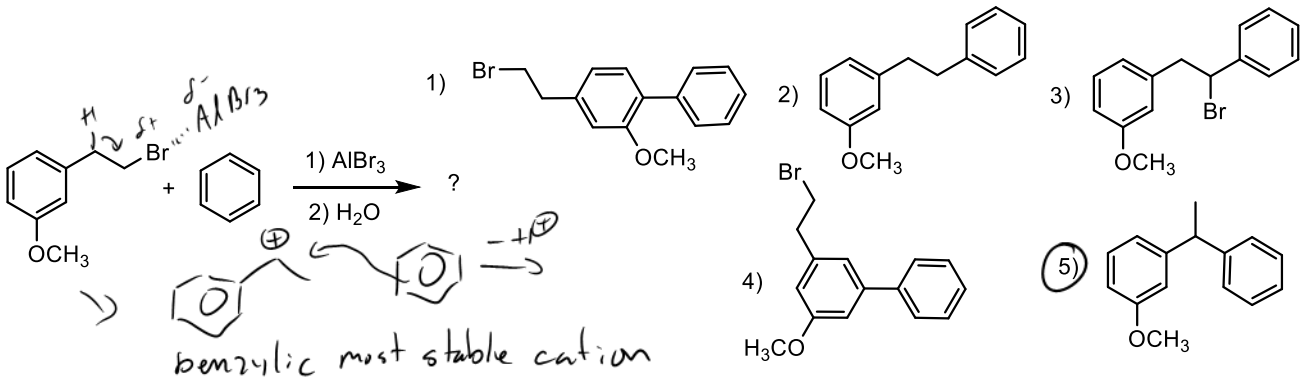


12) What is/are the **major** product(s) formed in the following reaction?

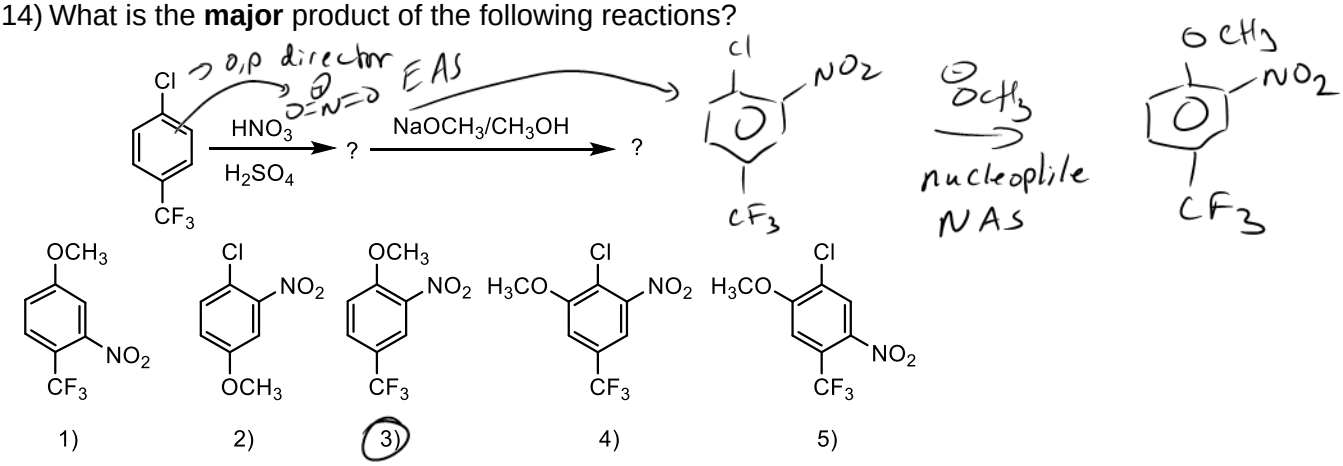
A) Only 1
B) Only 2
C) Only 3
D) Mixture of 2 and 3
E) All are formed in equal amounts



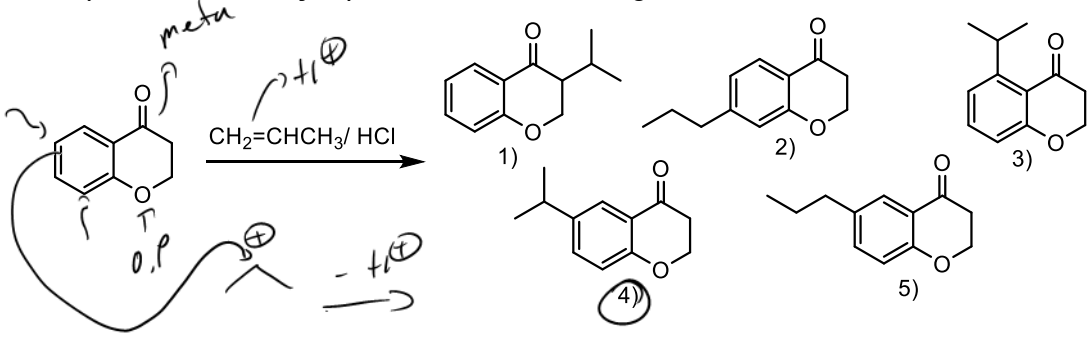
13) What is the **major** product of the following reaction?



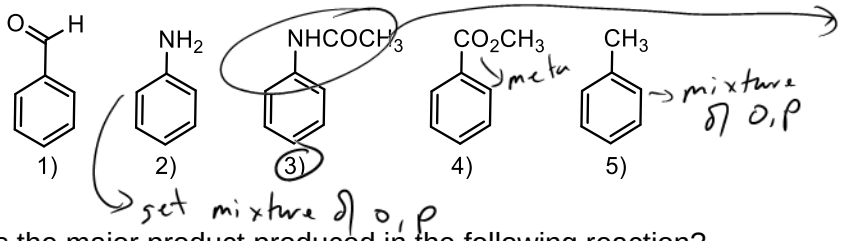
14) What is the **major** product of the following reactions?



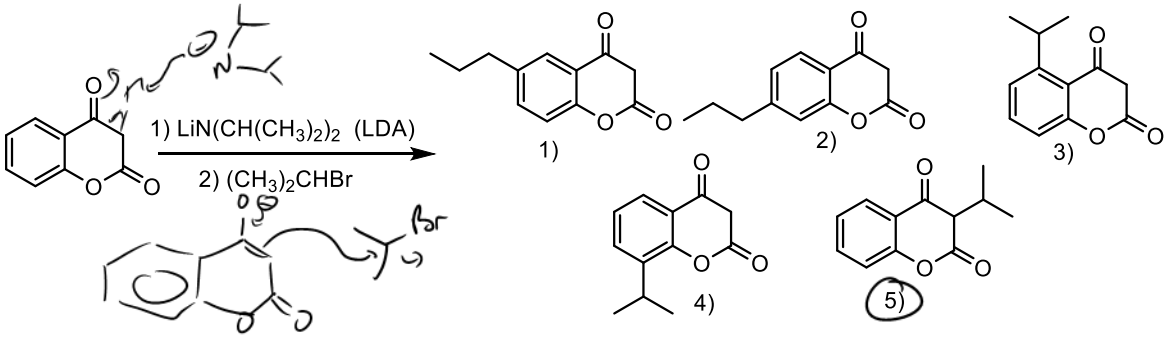
15) What is the **major** product of the following reaction?



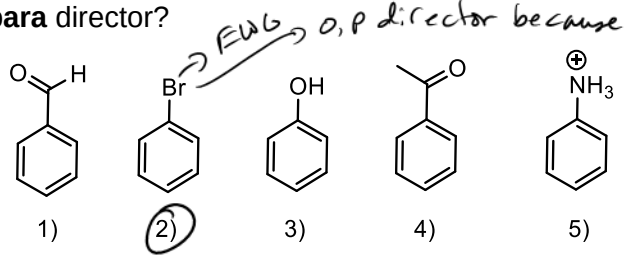
16) Which of the following compounds listed below would you expect to give the **greatest percentage** of para-product when subjected to ring nitration?



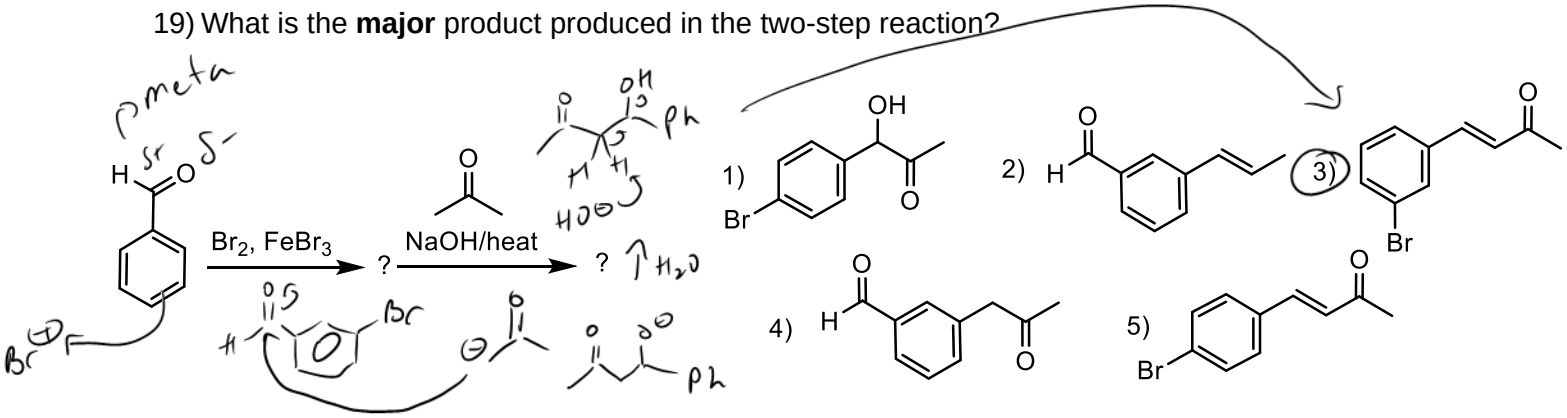
17) What is the major product produced in the following reaction?



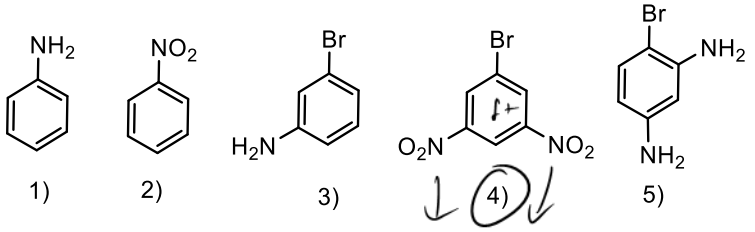
18) Which of the following compounds is **less** reactive than benzene towards ring nitration and is also an **ortho-para** director?

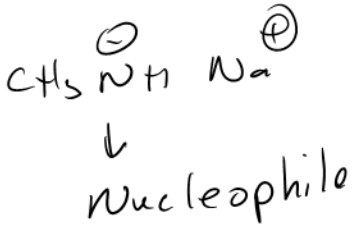


19) What is the **major** product produced in the two-step reaction?

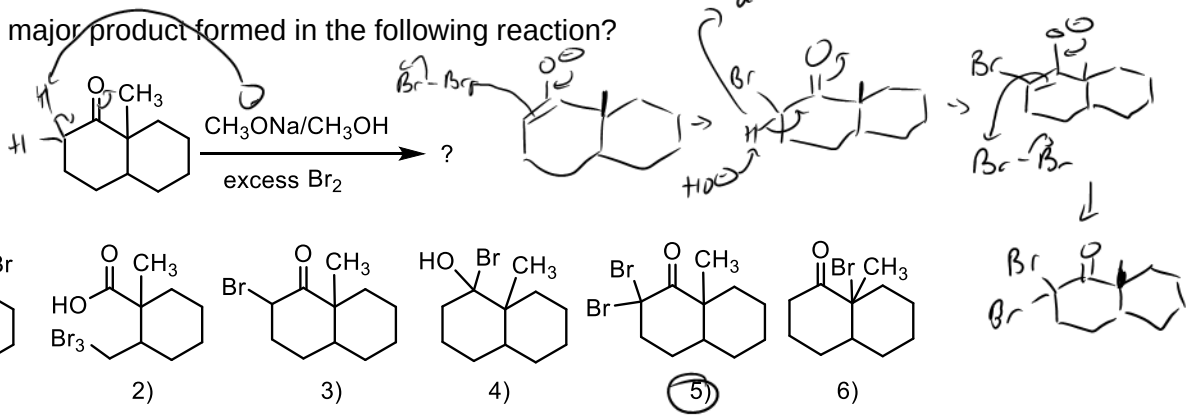


20) Which compound reacts most rapidly with CH_3NHNa?

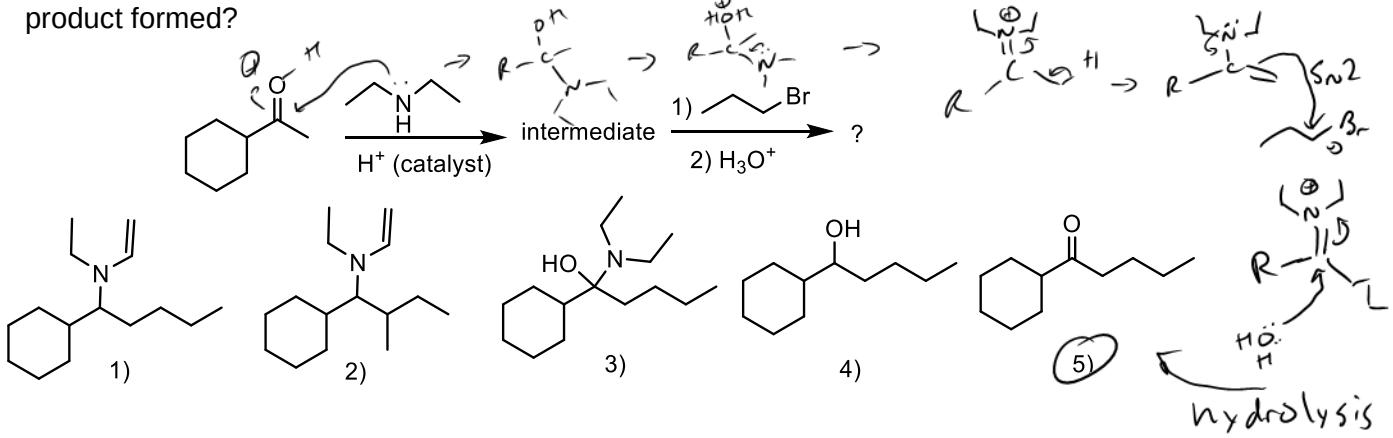




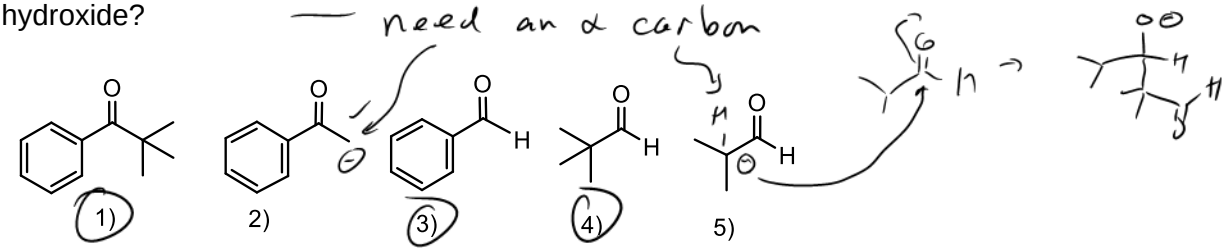
21) What is the major product formed in the following reaction?



22) The following reaction produces an intermediate, which is then reacted with an alkyl halide. This product is not isolated but treated with a dilute acid to produce the final product. What is the final product formed?

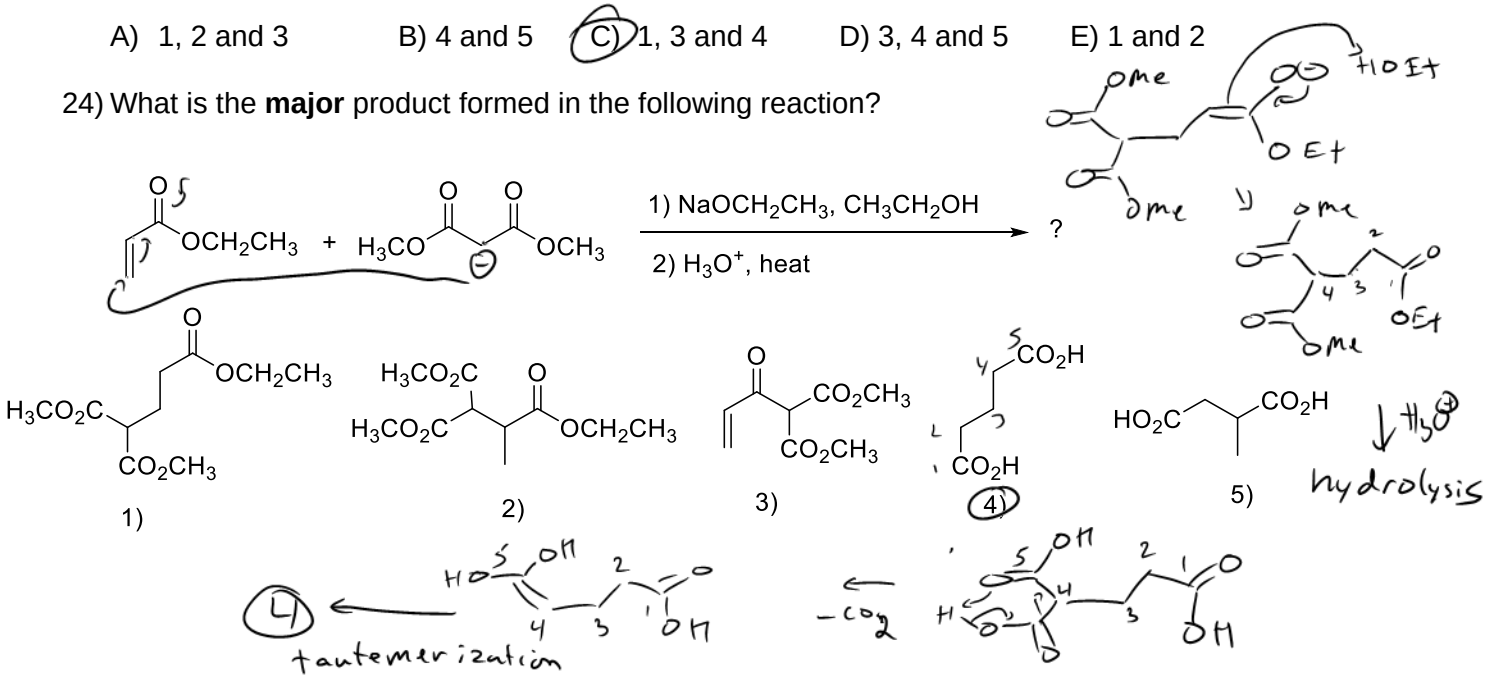


23) Which aldehyde or ketone can **NOT** undergo a self-condensation reaction when reacted with sodium hydroxide?

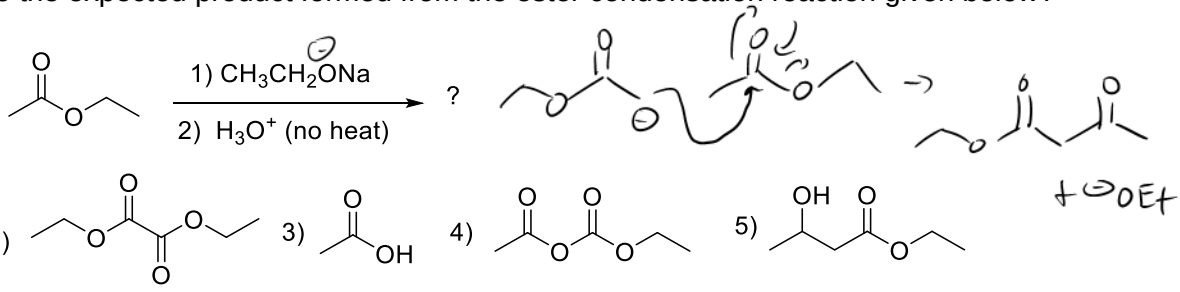


A) 1, 2 and 3 B) 4 and 5 C) 1, 3 and 4 D) 3, 4 and 5 E) 1 and 2

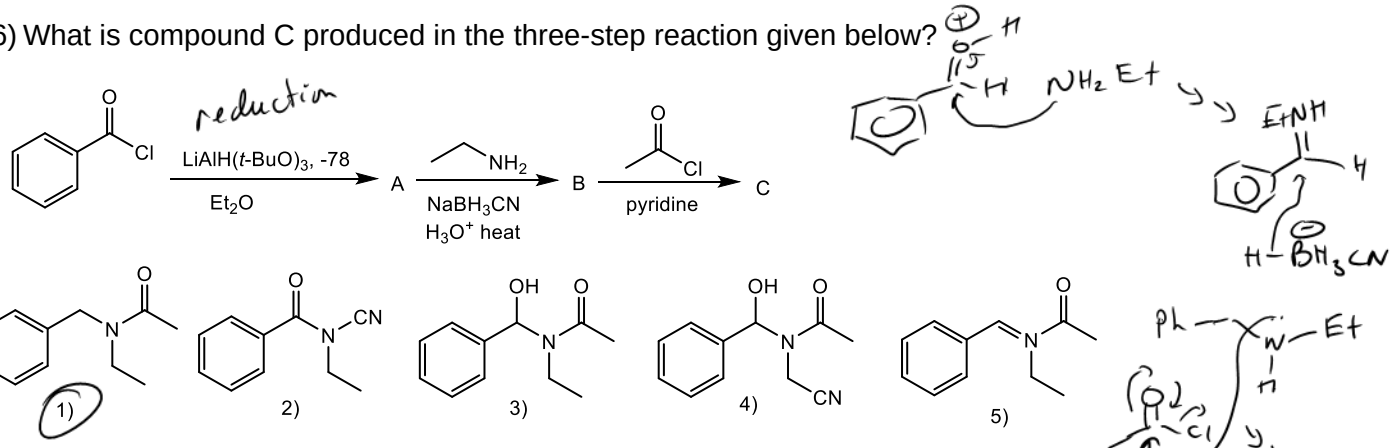
24) What is the **major** product formed in the following reaction?



25) What would be the expected product formed from the ester condensation reaction given below?

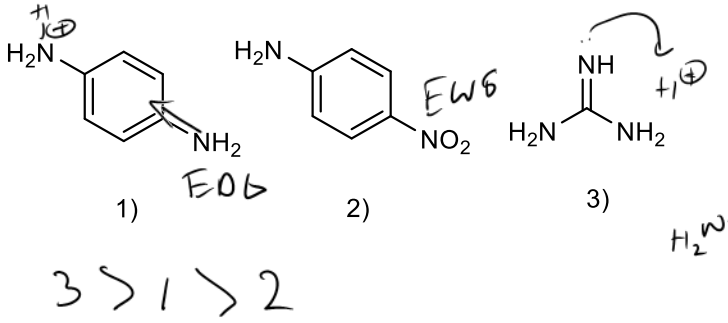


26) What is compound C produced in the three-step reaction given below?

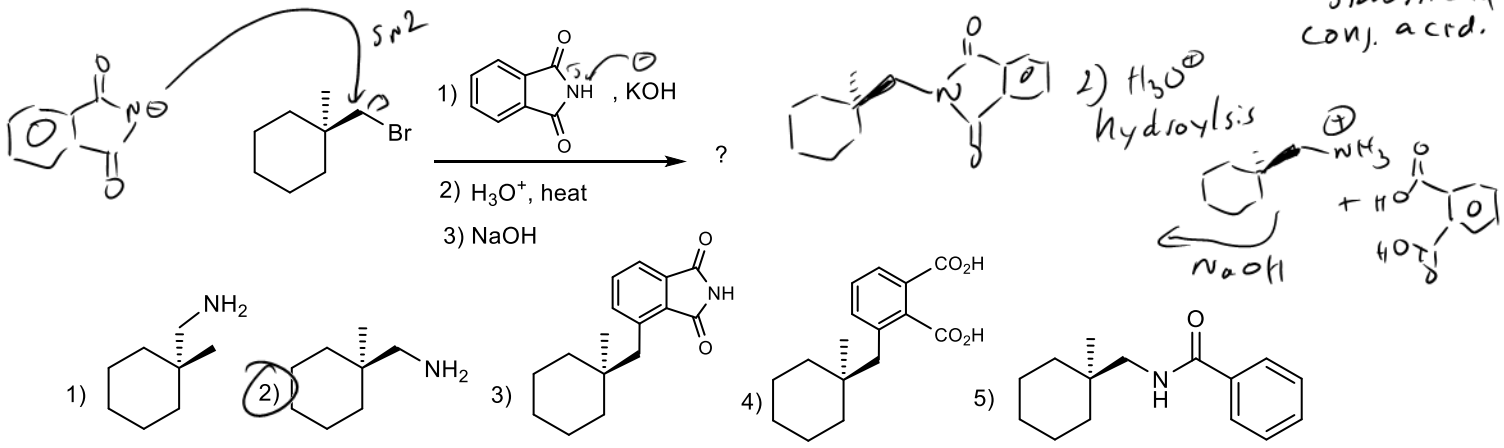


27) Order the following amines from strongest to weakest.

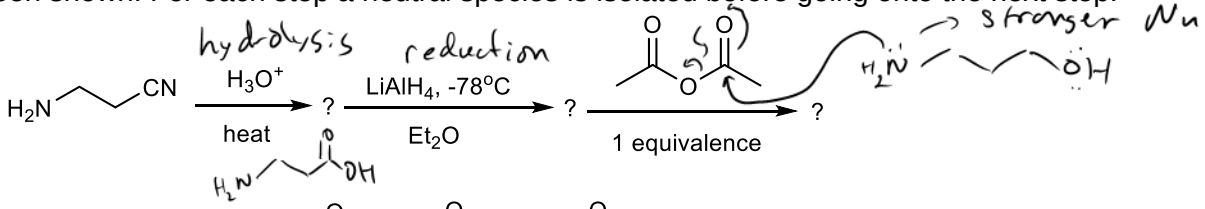
A) 1 > 2 > 3
B) 2 > 3 > 1
C) 3 > 2 > 1
D) 2 > 1 > 3
E) 3 > 1 > 2
F) 1 > 3 > 2

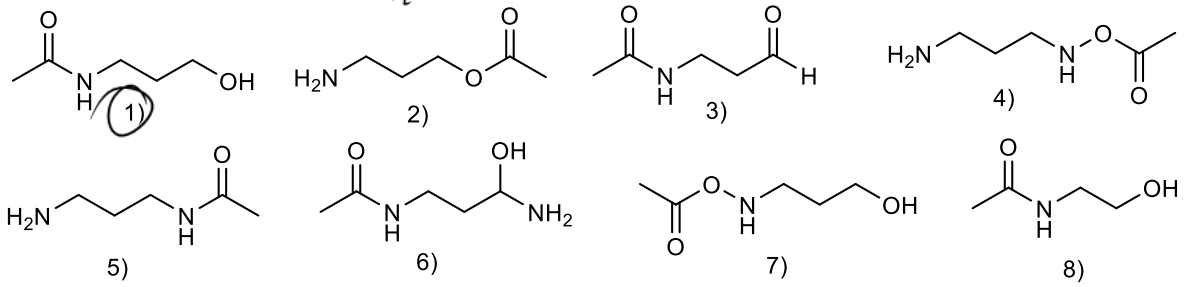


28) What is the product produced in the following reaction?

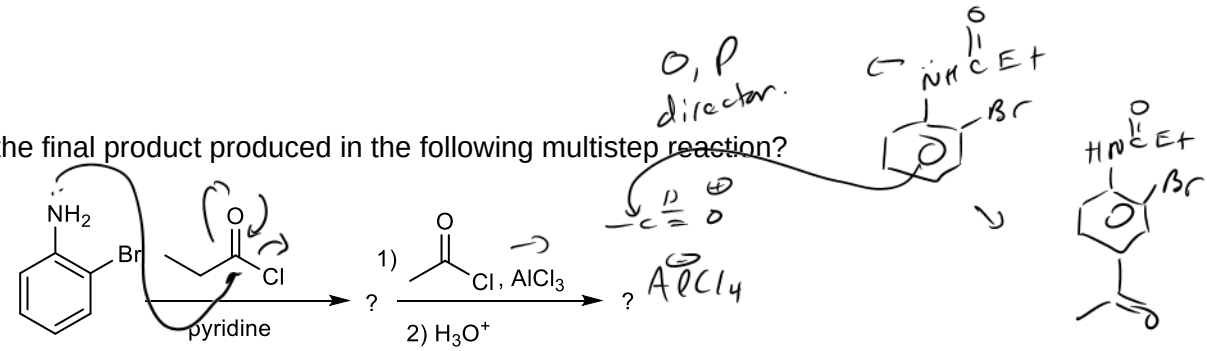


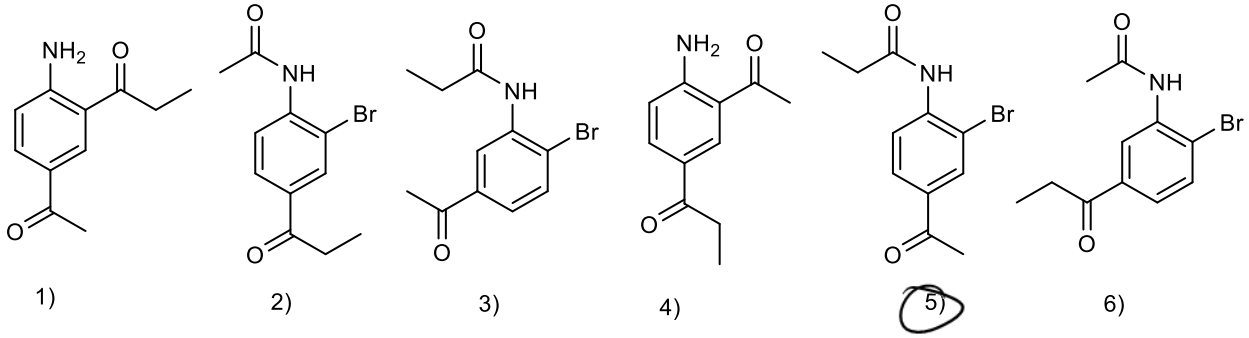
29) What is the final product produced in the following multistep reaction? **NOTE**: Workups have **not** been shown. For each step a neutral species is isolated before going onto the next step.





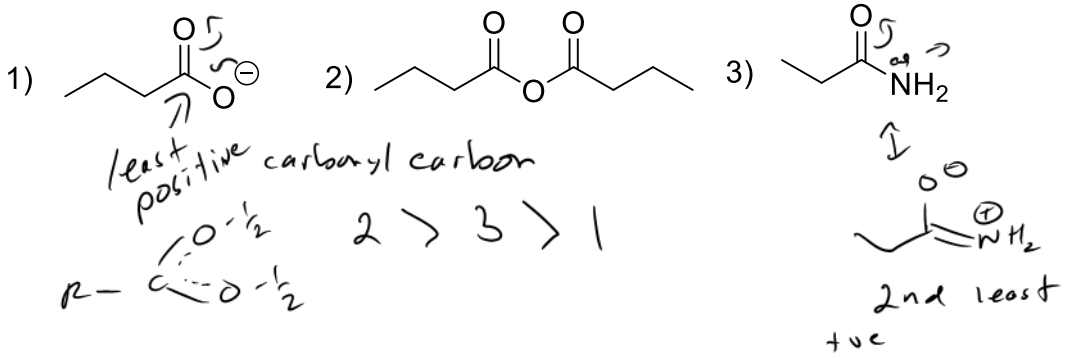
30) What is the final product produced in the following multistep reaction?



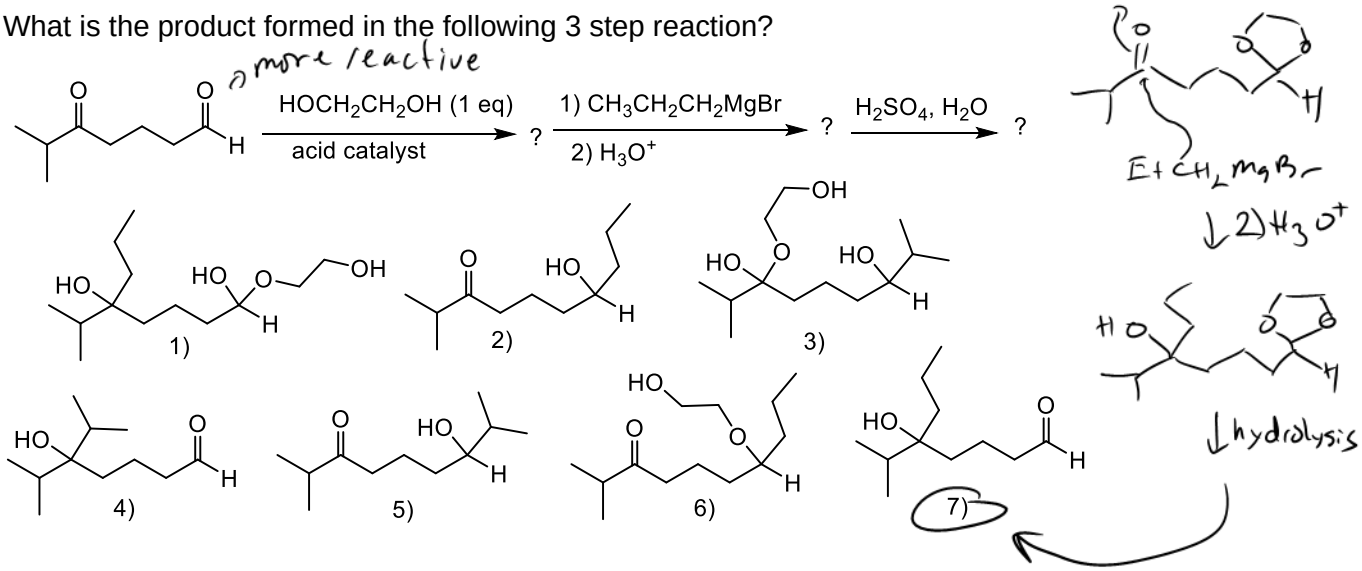


31) Order the following carboxylic acid derivatives from **most to least** reactive toward a nucleophilic attack on the carbonyl carbon:

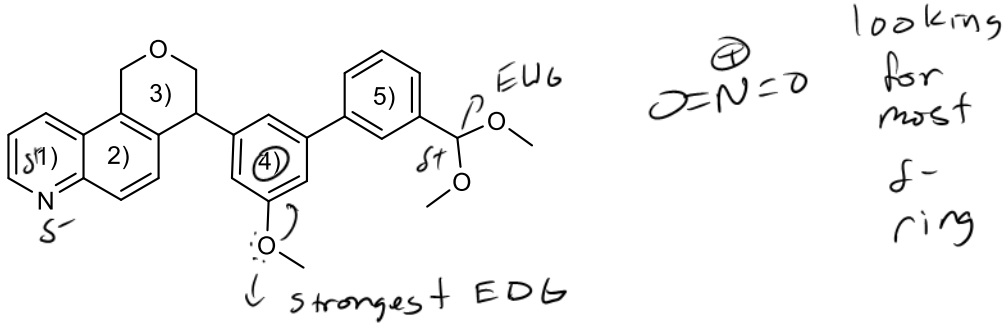
a) 1 > 2 > 3
b) 1 > 3 > 2
c) 2 > 3 > 1
d) 2 > 1 > 3
e) 3 > 2 > 1
f) 3 > 1 > 2



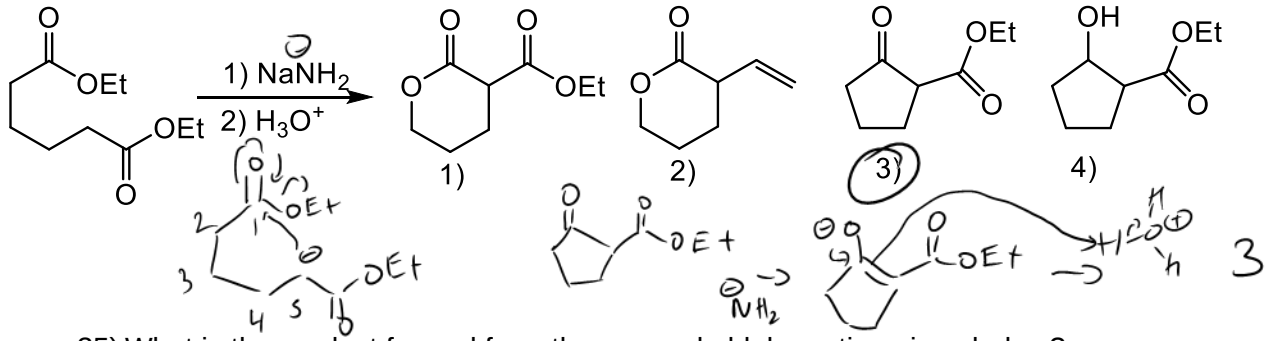
32) What is the product formed in the following 3 step reaction?



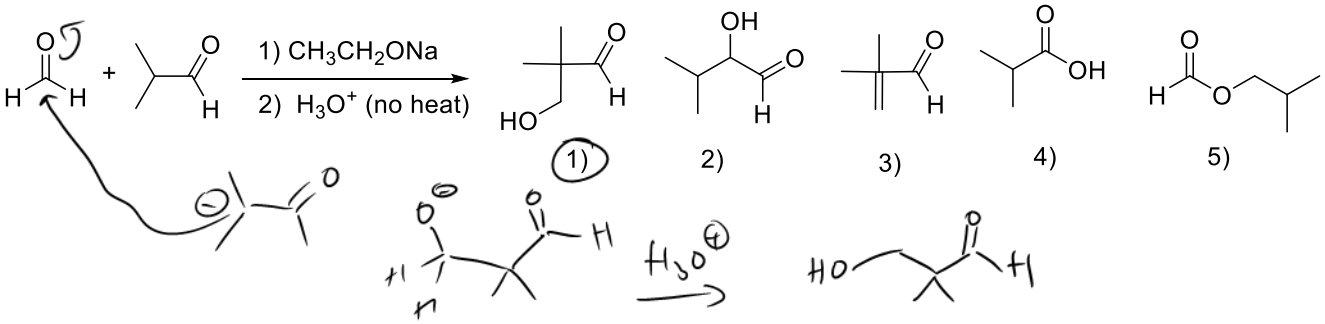
33) In the molecule below which aromatic ring would react fastest towards ring nitration?



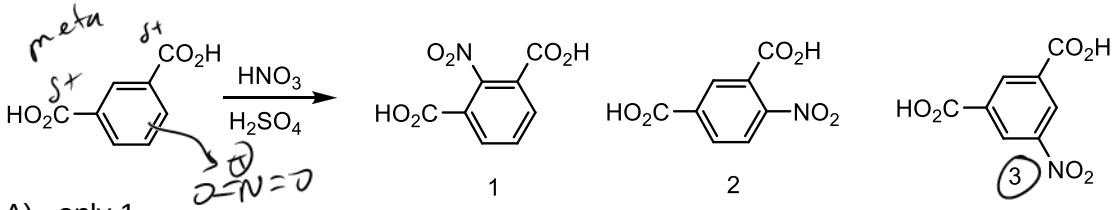
34) What is the product produced in the following reaction?



35) What is the product formed from the crossed aldol reaction given below?

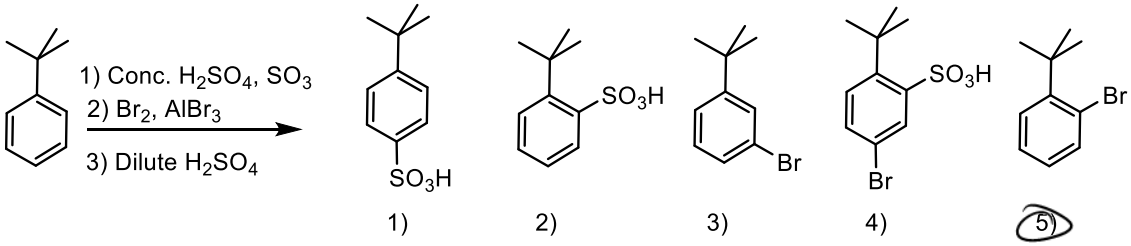


36) The **major** product(s), of the following reaction, would be

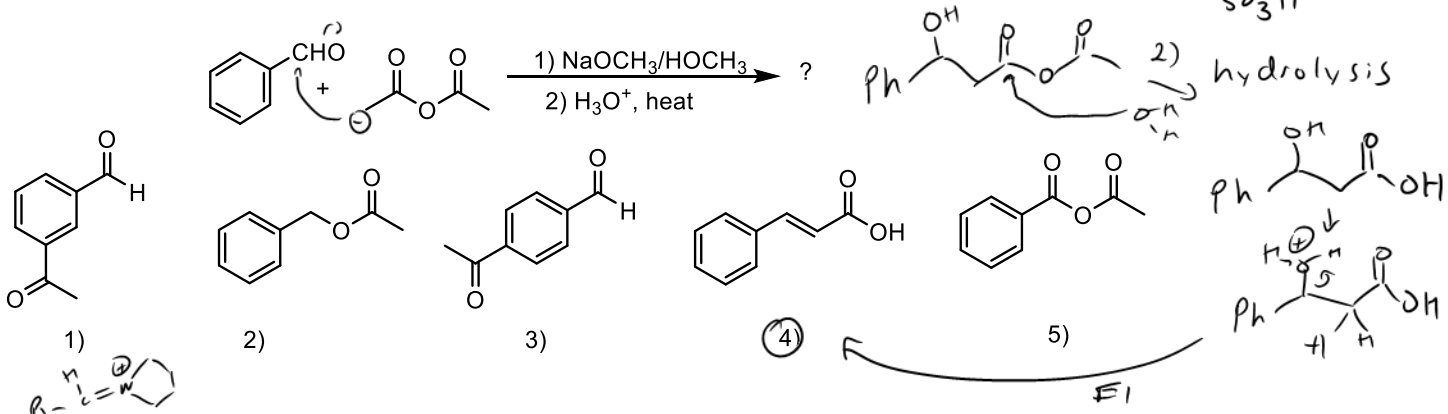


A) only 1
B) only 2
C) only 3
D) A mixture of 1 and 2
E) Equal amounts of 1, 2 and 3

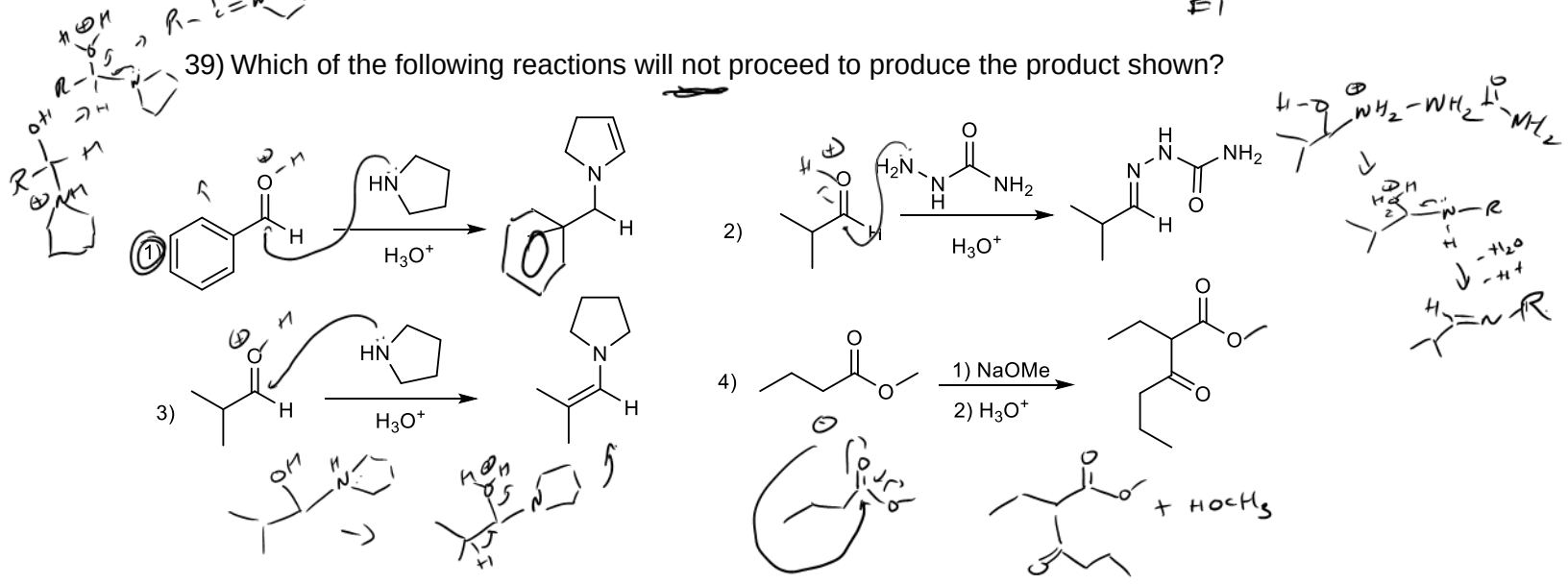
37) What is the major product of the following reactions?



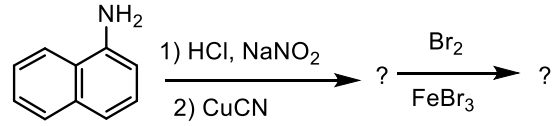
38) What is the product formed in the following reaction?

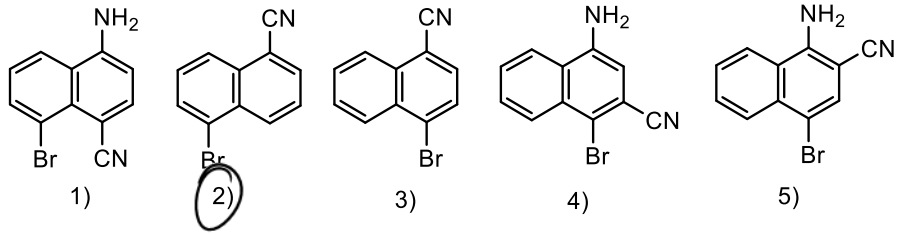


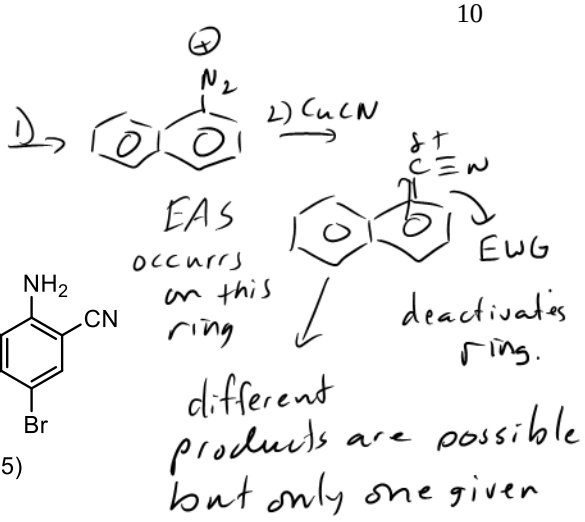
39) Which of the following reactions will not proceed to produce the product shown?



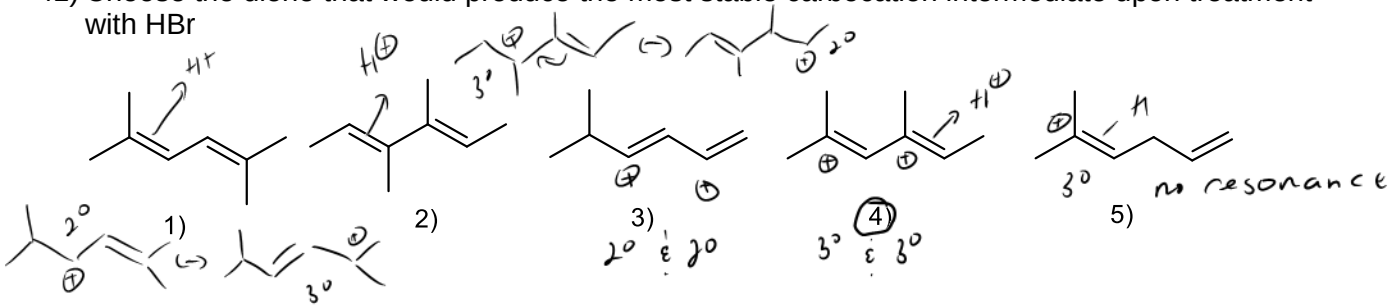
40) What is the product formed in the following reactions?



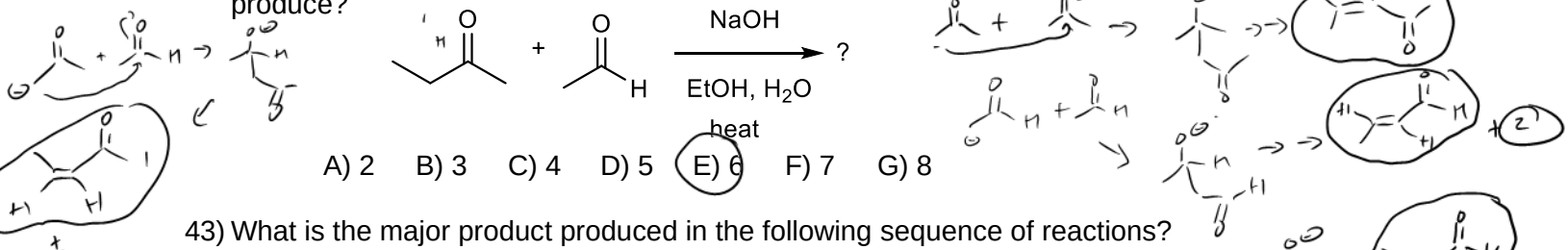




41) Choose the diene that would produce the most stable carbocation intermediate upon treatment with HBr

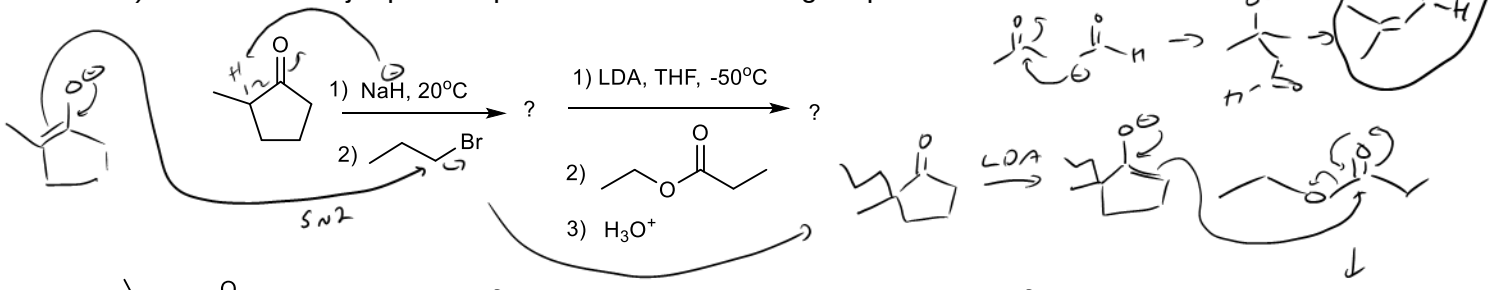


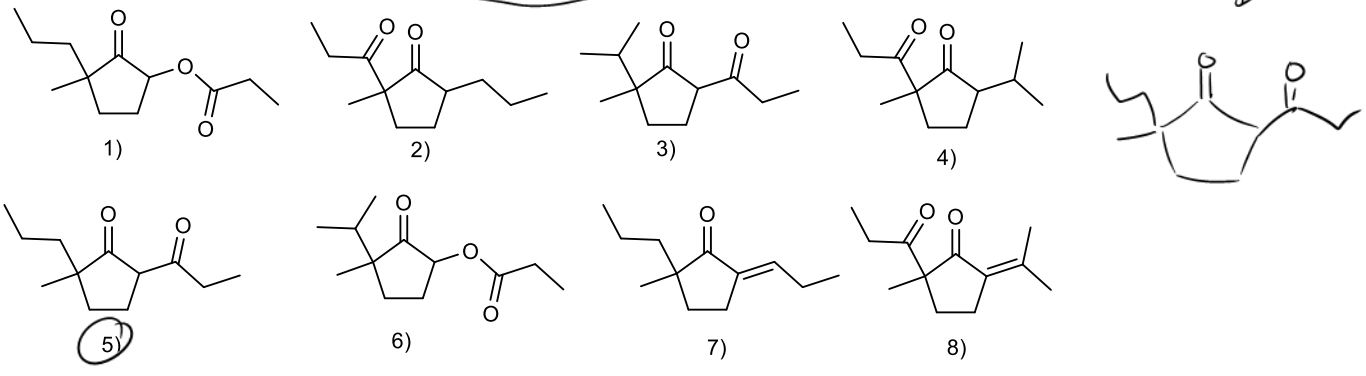
42) The following crossed aldol condensation reaction was completed by combining the ketone the aldehyde together in a flask then adding the base. This was a poorly designed reaction because it produced many different products. How many crossed aldol products could this reaction produce?



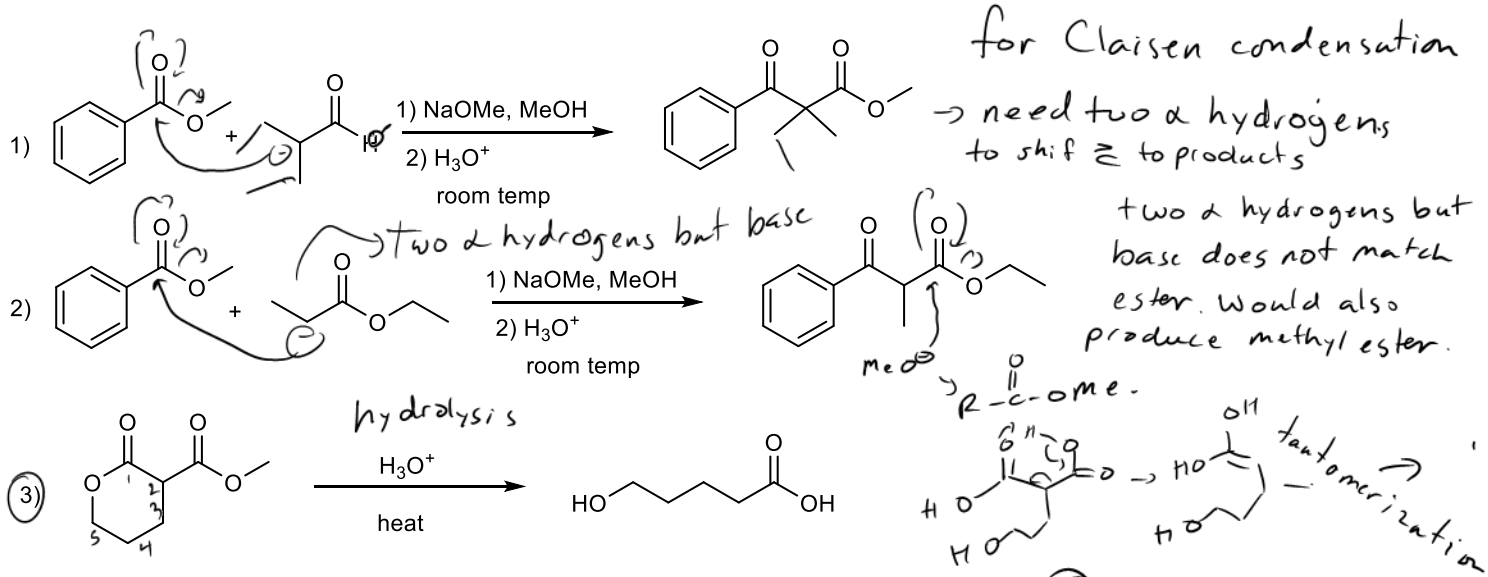
A) 2 B) 3 C) 4 D) 5 E) 6 F) 7 G) 8

43) What is the major product produced in the following sequence of reactions?



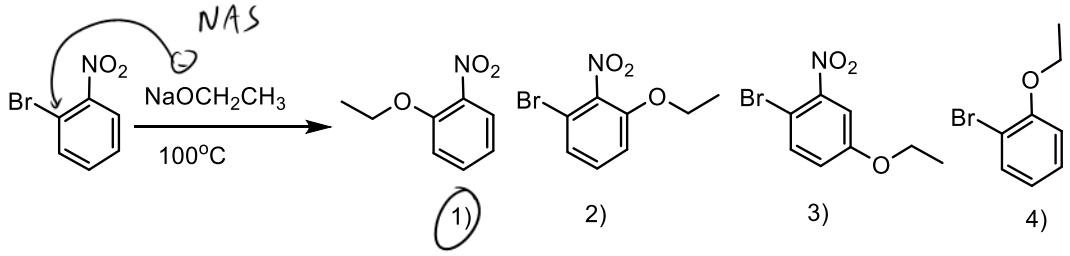


44) Which of the following reactions will produce the given products in good yield?

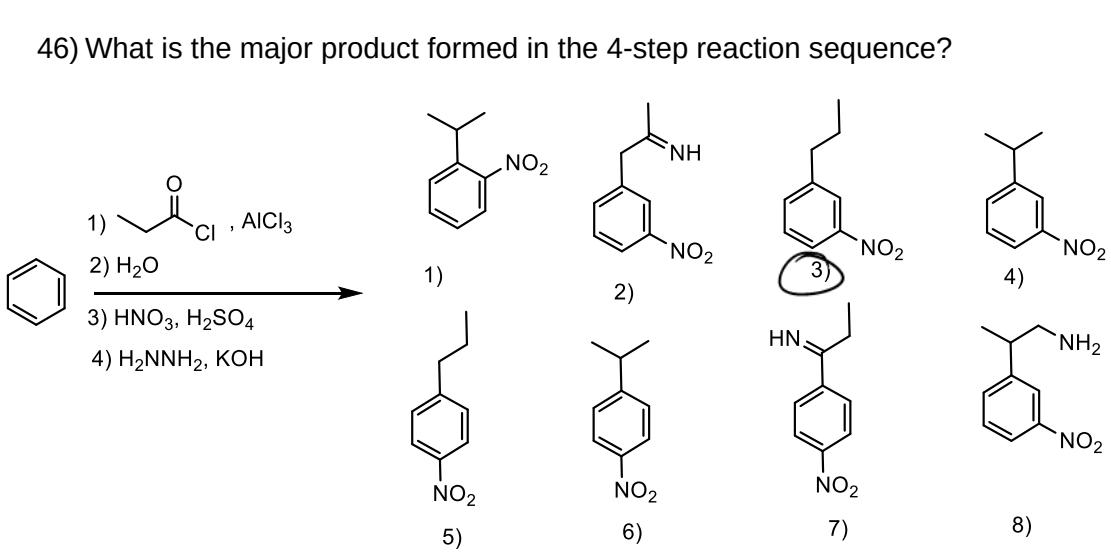


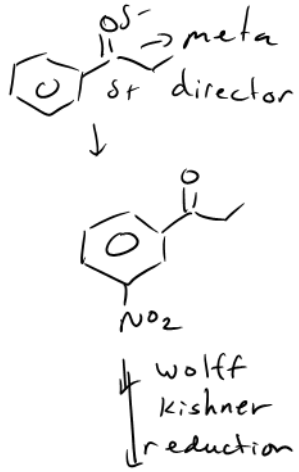
A) 1, 2 and 3 B) 1 and 2 C) 1 and 3 D) 2 and 3 E) only 1 F) only 2 G) only 3

45) What is the product of the following reaction?

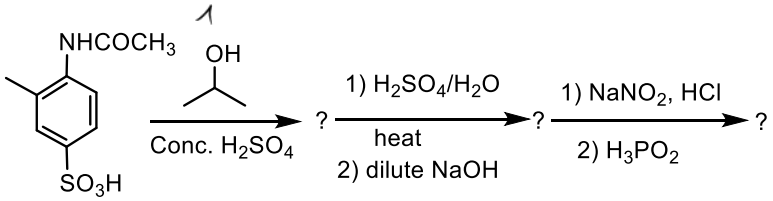


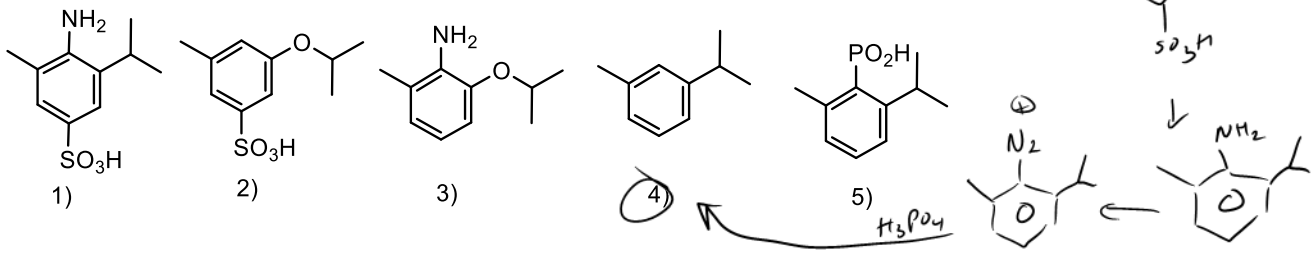
46) What is the major product formed in the 4-step reaction sequence?





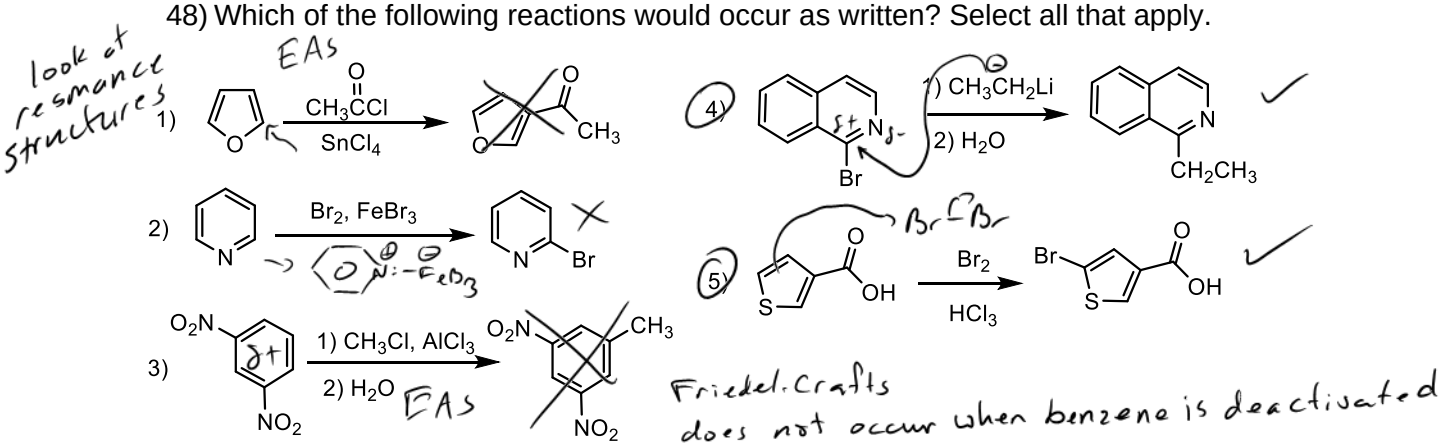
47) What is the final product formed in the following sequence of reactions?



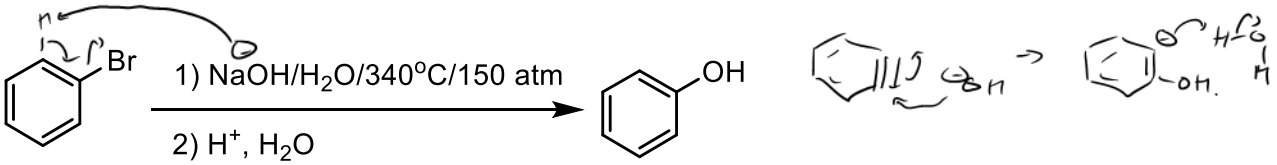


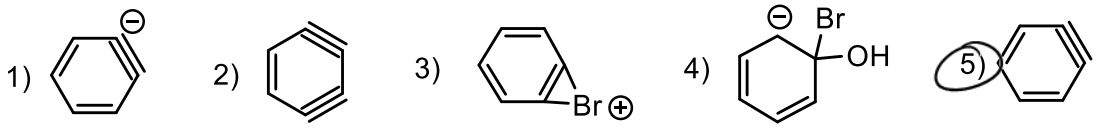
48) Which of the following reactions would occur as written? Select all that apply.

look at resonance structures



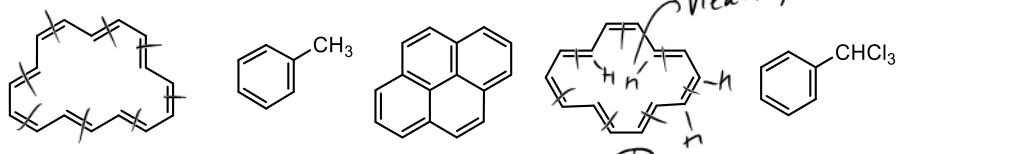
49) When considering the mechanism of the reaction shown below, which of the following is **most likely** an **intermediate** along the reaction pathway?



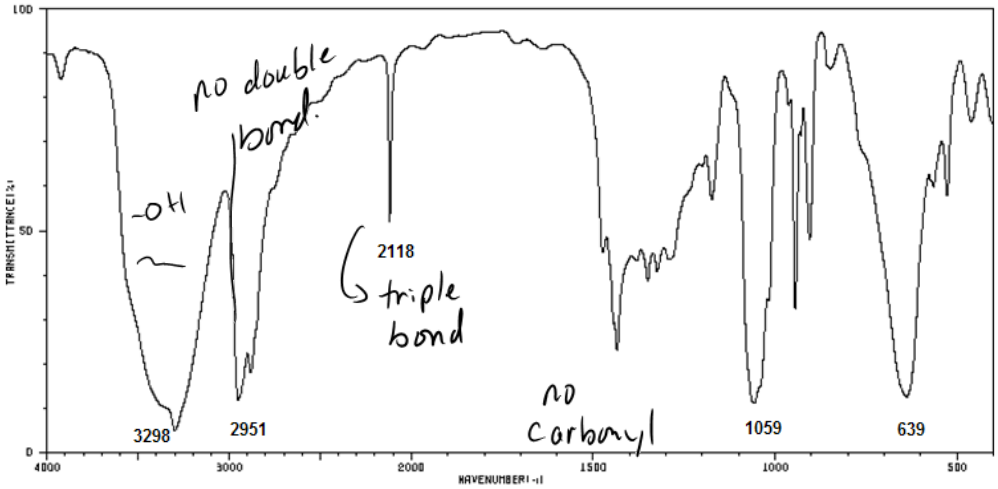


50) Which of the following compounds would have a ^{1}H NMR that would show only two peaks, with one absorption peak δ 7 ppm and the other at δ -1 ppm?

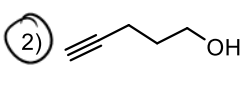
16 π not aromatic

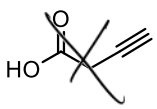


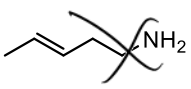
51) Using the IR spectrum shown below; what is the most likely structure of the compound?



1) 

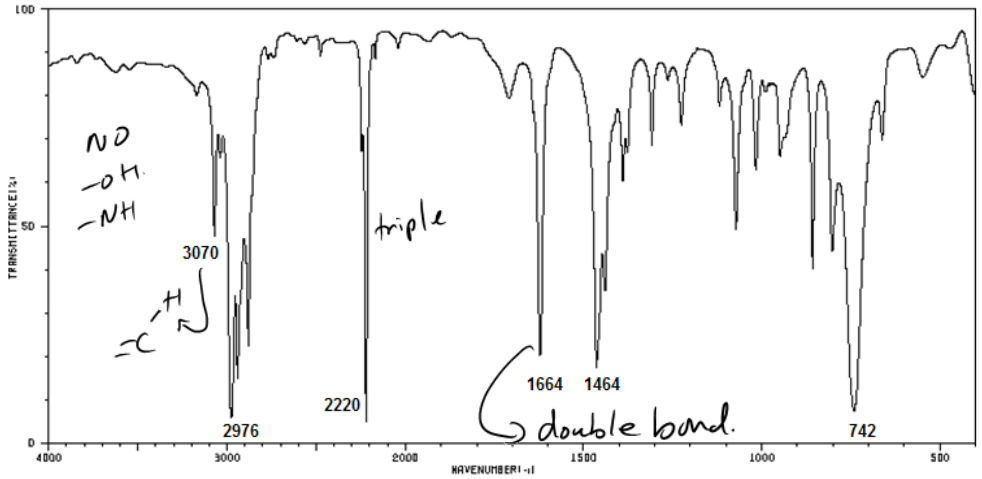
2) 

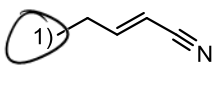
3) 

4) 

5) 

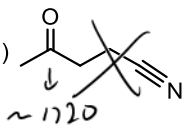
52) Using the IR spectrum shown below; what is the most likely structure of the compound?

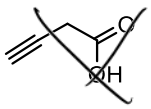


1) 

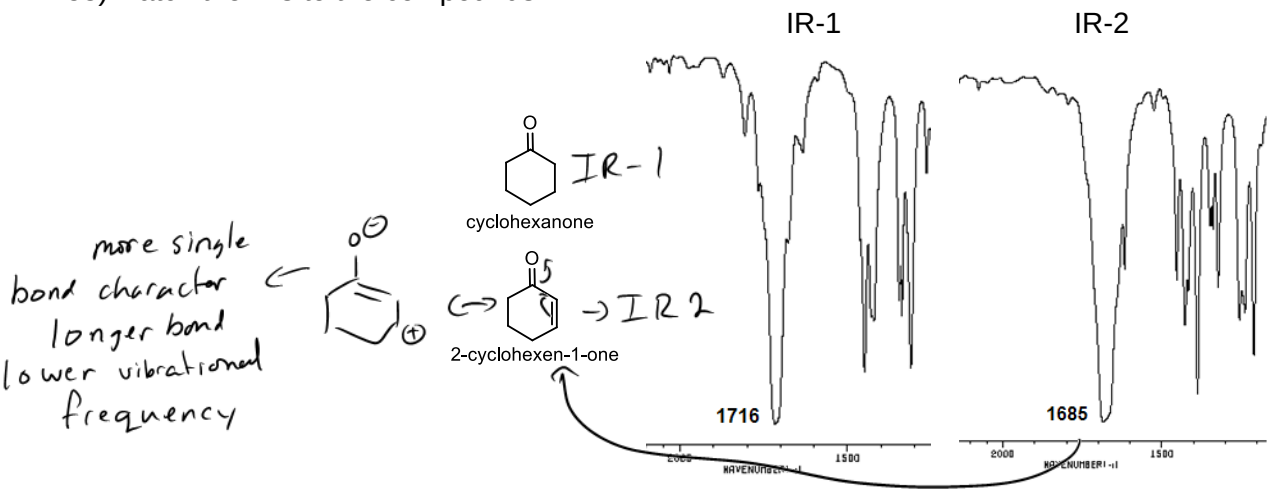
2) 

3) 

4) 

5) 

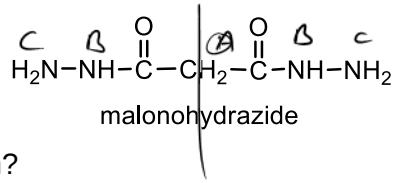
53) Match the IRs to the compounds.



A) IR-1; cyclohexanone IR-2; 2-cyclohexen-1-one
B) IR-1; 2-cyclohexen-1-one IR-2; cyclohexanone

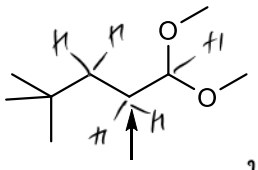
54) How many signals would you expect to find in the ^{1}H NMR spectrum of malonohydrazide?

A) 2 B) 3 C) 4 D) 5 E) 6



55) Predict the multiplicity of the indicated hydrogen?

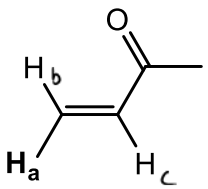
A) Singlet
B) Doublet
C) Triplet
D) Quartet
E) Quintet
F) Sextet
G) Doublet of doublets



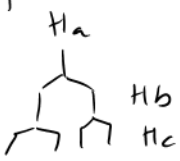
sees 3 ∴ quartet

56) What splitting pattern would H_a exhibit?

H) Singlet
I) Doublet
J) Triplet
K) Quartet
L) Doublet of Doublets



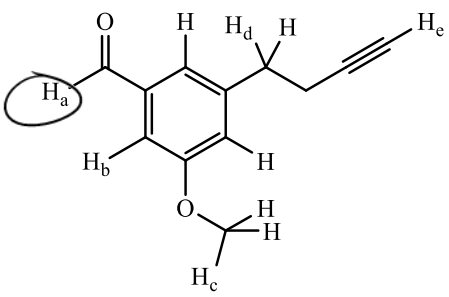
the alkene hydrogens are not chemically equivalent



57) Which of the following protons would be deshielded the **most**?

A) H_a
B) H_b
C) H_c
D) H_d
E) H_e

look at the chart



58) What is the index of hydrogen deficiency if the molecular formula of an unknown molecule is $C_{12}H_{16}O_2$?

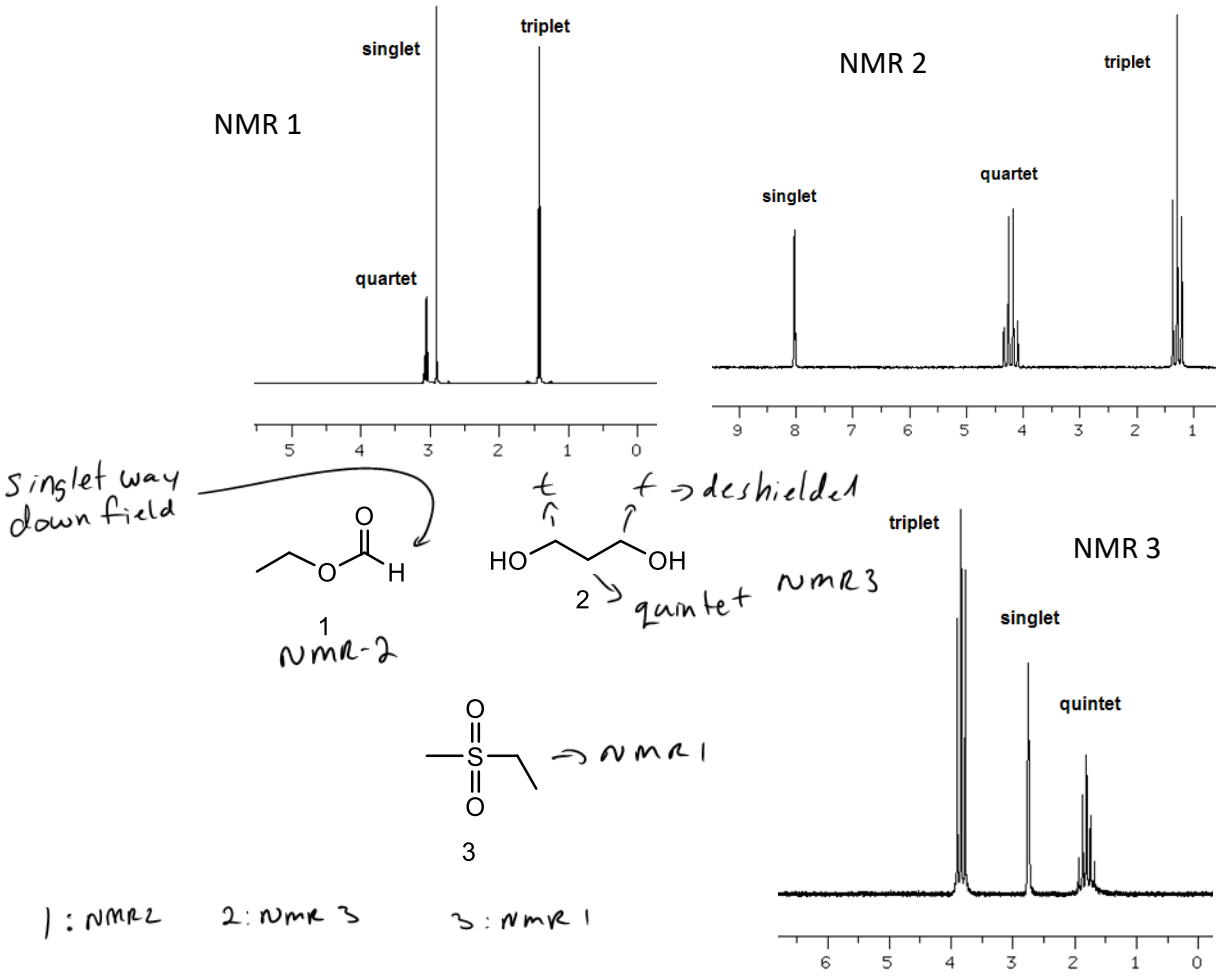
A) 3 B) 4 C) 5 D) 6 E) 7

$C_{2n+2}H_n$

$26-16=\frac{10}{2}=5$

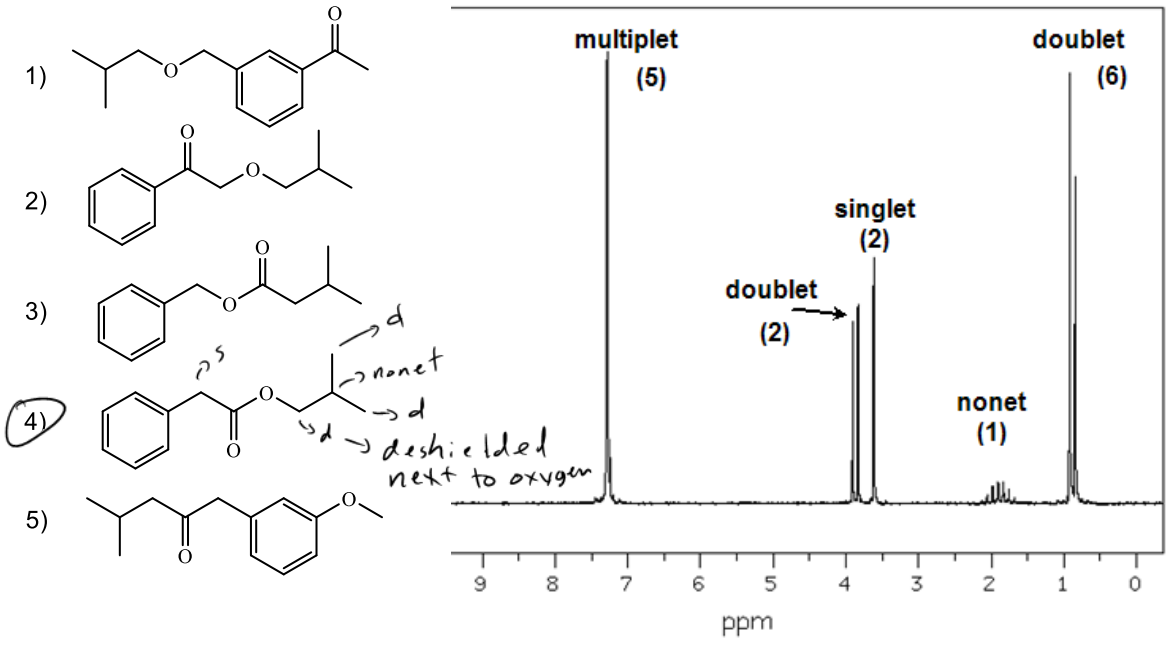
oxygen does not change

59) Match the ^{1}HNMR with the following compounds.



A) Compound 1 : NMR 1, Compound 2 : NMR 2, Compound 3 : NMR 3
B) Compound 1 : NMR 1, Compound 2 : NMR 3, Compound 3 : NMR 2
C) Compound 1 : NMR 2, Compound 2 : NMR 1, Compound 3 : NMR 3
D) Compound 1 : NMR 2, Compound 2 : NMR 3, Compound 3 : NMR 1
E) Compound 1 : NMR 3, Compound 2 : NMR 1, Compound 3 : NMR 2
F) Compound 1 : NMR 3, Compound 2 : NMR 2, Compound 3 : NMR 1

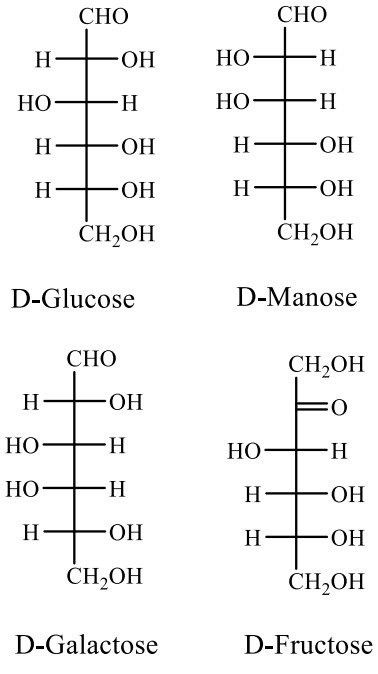
60) Match the ^{1}H NMR with the compound given below that has the molecular formula $C_{12}H_{16}O_2$ and a carbonyl IR peak at 1741 cm^{-1}.



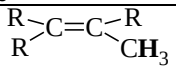
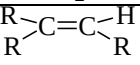
Some Characteristic infrared IR absorptions (cm-1)

Group	Frequency Range (cm^{-1})
Alkyl C-H	2853-2962
	1350 - 1470
Alkene C-H	3010-3095
Alkyne C-H	≈ 3300
Aromatic C-H	≈ 3030
Aldehyde C-H	2700 - 2740
Alkene C = C	1640 - 1680
Aromatic C = C	1500, 1600
Alkyne C≡C	2100 – 2260
C – O	1000 - 1300
C = O	1690 – 1760
Alcohol O – H	3610 – 3640
Phenol O – H	or 3200 – 3600
Carboxylic acid O – H	2500 – 3500 (broad) often overlaps C-H region
C≡N	2200-2260
N-H	3300 - 3500
N-H	1640 – 1620

Sugars



Some approximate 1H NMR chemical shifts

Type of Proton	Chemical Shift (□, ppm)
1° Alkyl, RCH_3	0.8 – 1.0
2° Alkyl, RCH_2R	1.2 – 1.4
3° Alkyl, R_3CH	1.4 – 1.7
Allylic, 	1.6 – 1.9
Ketone, RCH_2COCH_2R	2.1 – 2.6
Benzylic, Ar-CH_3	2.2 – 2.5
Acetylenic RC≡CH	2.5 – 3.0
Alkyl iodide, RCH_2I	3.1 – 3.3
Ether, $ROCH_2R$	3.3 – 3.9
Ester, $RCOOCH_2R$	3.5 – 4.5
Alcohol, RCH_2-OH	3.3 – 4.0
Alkyl bromide RCH_2Br	3.4 – 3.6
Alkyl chloride, RCH_2Cl	3.6 – 3.8
Vinylic, $R_2C=CH_2$	4.6 – 5.0
Vinylic 	5.2 – 5.7
Aromatic, ArH	6.0 – 9.5
Aldehyde, RCH_2COH	9.5 – 10.5
Alcohol hydroxyl, ROH	0.5 – 6.0 [a]
Amino R-NH_2	1.0 – 5.0 [a]
Phenolic, Ar-OH	4.5 – 7.7 [a]
Carboxylic, RCH_2CO_2H	10 – 13[a]

[a] The chemical shift of these protons vary in different solvents and with temperature and concentration.

Periodic chart

H 2.1																
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0
K 0.82	Ca 1.0	Sc 1.4	Ti 1.5	V 1.6	Cr 1.7	Mn 1.6	Fe 1.8	Co 1.9	Ni 1.9	Cu 2.0	Zn 1.7	Ga 1.8	Ge 2.0	As 2.2	Se 2.6	Br 2.8

Electronegativity →

Some[(a)] Characteristic infrared (IR) absorptions (cm^{-1})

Frequency (intensity[(b)], shape)	**Functional group**
3500-3600 (*m*, sharp)	Free O-H of alcohol stretch
3400-3600 (*s*, broad)	Hydrogen bonded alcohol stretch
3400-3600	Phenol O-H like alcohol stretch
3300-3500 (*m*)	Amine N-H (1° -2 peaks, 2° 1 peak) stretch
3300 (*s*, sharp)	Terminal alkyne (-C≡C-H) stretch
3000-3100 (*w* to *m*)	Alkene and Aromatic C-H stretch
2500-3400 (*s*, very broad)	Carboxylic acid O-H stretch
2800-3000 (*s*, sharp)	Alkyl C-H stretch
2700 and 2740 (*m*, sharp, 2)	Aldehyde O=C-H stretch
2700-2300 usually blank	Nothing organic in this region
2100-2260 (*w* to absent)	Alkyne (-C≡C- asymmetric), nitrile -C≡N
1670-1800 (*s* to very strong)	Carbonyl in ketone, aldehyde, acid, etc, etc
1625-1689 (*m* to zero)	Alkene (C=C, asymmetric)
1500-1600 (variable)	Aromatic (C=C)
1350-1475 (*m*, several peaks)	Alkyl C-H bending
1400-600 many and variable	"Fingerprint" region with many peaks for various functional groups
<600 (usually not plotted)	"heavy" atoms, like chlorine

(a) A proper set of tables would be 10-15 pages long *(b) S = strong, m = medium, w = weak*

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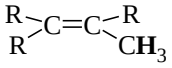
Allylic, 	1.6 – 1.9
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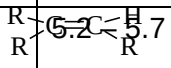
Ester, $RCOOCH_2R$	3.5 – 4.5
Alcohol, RCH_2-OH	3.3 – 4.0
Alkyl bromide RCH_2Br	3.4 – 3.6
Alkyl chloride, RCH_2Cl	3.6 – 3.8
Vinylic, $R_2C=CH_2$	4.6 – 5.0
Vinylic 	5.2 – 5.7
Aromatic, ArH	6.0 – 9.5
Aldehyde, RCH_2COH	9.5 – 10.5
Alcohol hydroxyl, ROH	0.5 – 6.0 [a]
Amino R-NH_2	1.0 – 5.0 [a]
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Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0
K 0.82	Ca 1.0	Sc 1.4	Ti 1.5	V 1.6	Cr 1.7	Mn 1.6	Fe 1.8	Co 1.9	Ni 1.9	Cu 2.0	Zn 1.7	Ga 1.8	Ge 2.0	As 2.2	Se 2.6	Br 2.8

Electronegativity →