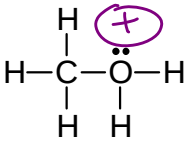
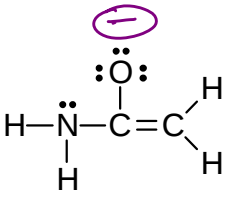
Before starting the exam, be sure that you have correctly entered your:

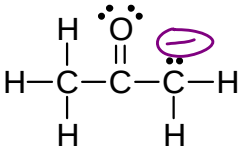
- Student number
- Exam code

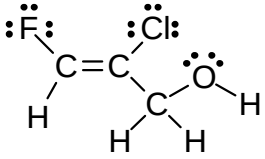
1. All valence electrons are shown for the Lewis structures below. Which species bears an overall positive charge (*i.e.* is a cation)?

A) 

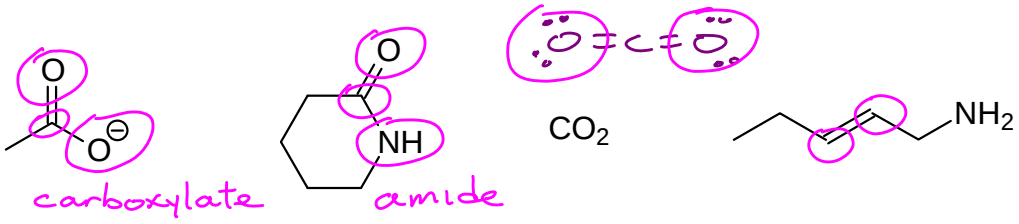
B) 

C) 

D) 

E) 

2. How many of the following species contain exactly three sp^2-hybridized atoms?



A) 3

B) 2

C) None

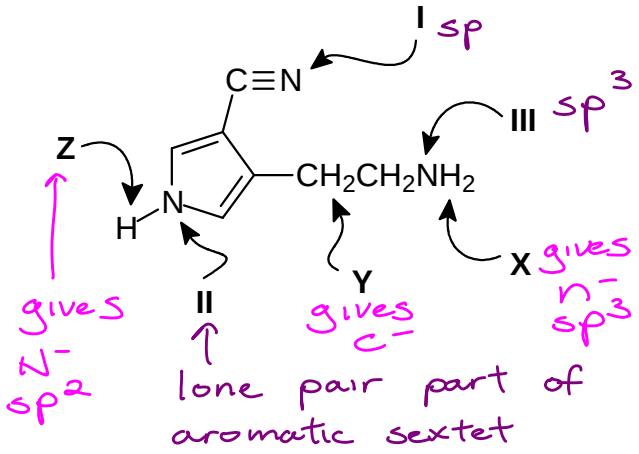
D) 1

E) 4

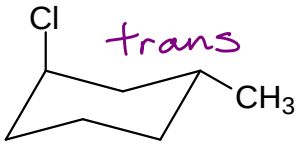
3. Histamine, one of the compounds responsible for the symptoms associated with allergies, is shown below. Which N atom is the most basic, and which H atom is the most acidic?

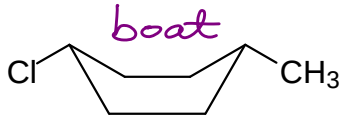
least-stable base ← most-stable conjugate base

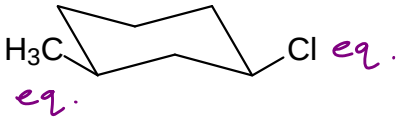
	most basic N	most acidic H
A)	III	X
B)	III	Z
C)	I	Z
D)	II	Z
E)	I	Y

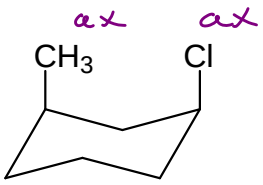


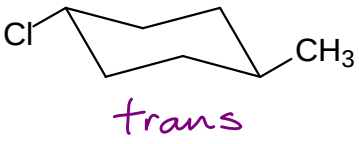
4. Which one of the following is the most stable conformation of *cis*-1-chloro-3-methylcyclohexane? (from notes)

A)


B)


C)


D)


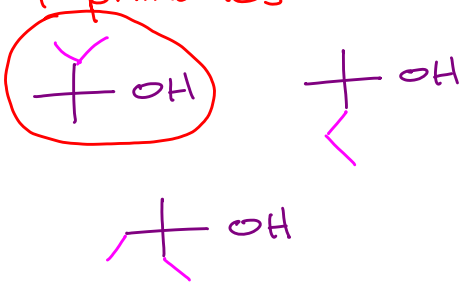
E)


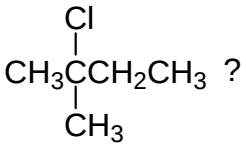
5. How many constitutional isomers of $C_6H_{14}O$ contain exactly one tertiary alcohol and four primary carbons?

must contain + OH (tertiary alcohol)
↖ accounts for 4 C, need 2 more

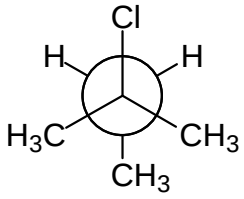
A) 4
B) None
C) 2
D) 3
E) 1

4 primaries

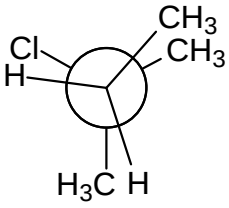


6. Which one of the following is not a conformation of  ?

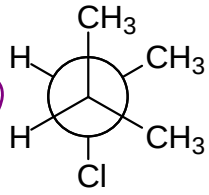
A)



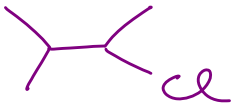
B)



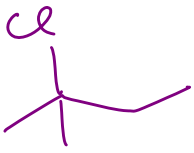
C)



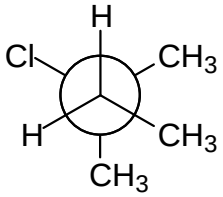
same as



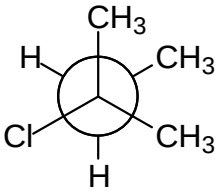
not



D)

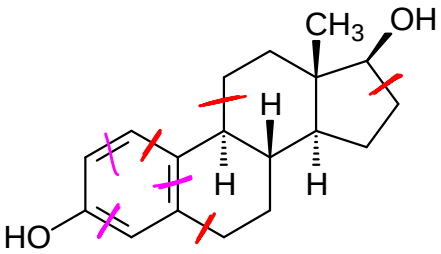


E)



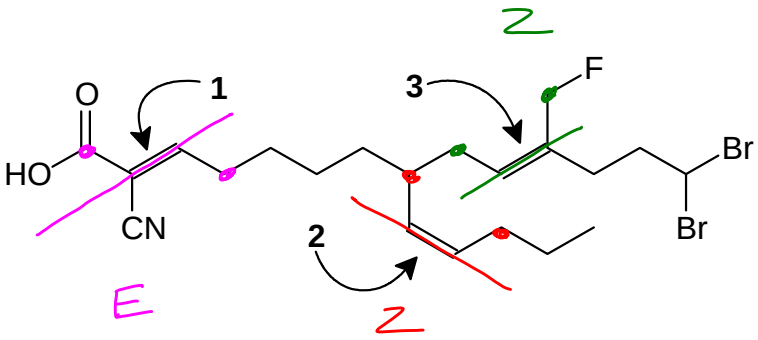
7. How many units of unsaturation are in the female sex hormone, *estradiol*?

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



3 π
4 rings

8. Assign *E*/*Z* configuration to each of the three alkenes in the compound below.

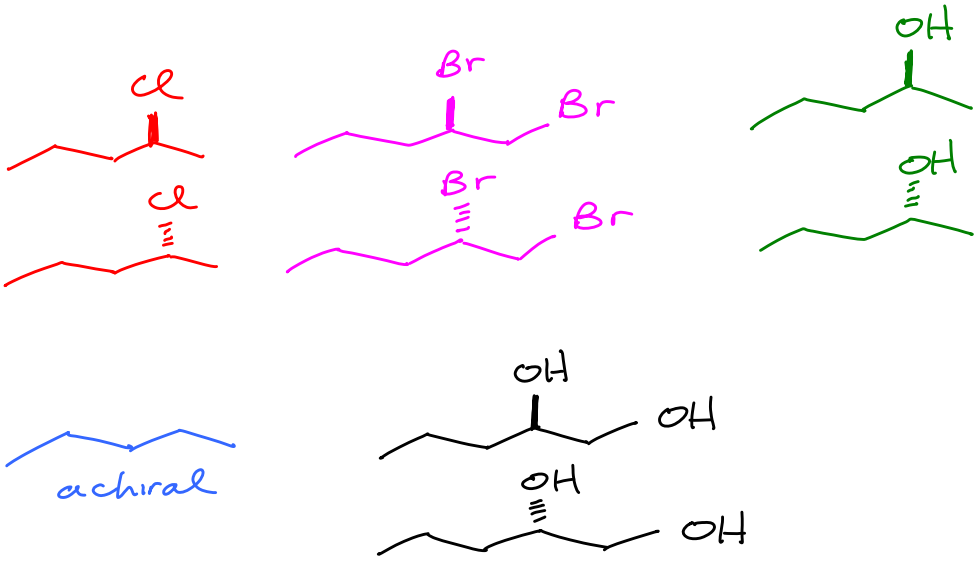


	1	2	3
A)	*E*	*Z*	*Z*
B)	*Z*	*E*	*E*
C)	*Z*	*E*	*Z*
D)	*Z*	*Z*	*E*
E)	*E*	*Z*	*E*

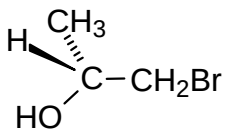
9. How many of the following reagents give a racemic product mixture upon reaction with 1-pentene?

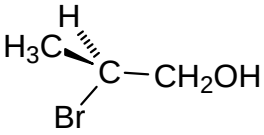
HCl Br_2 H^+/H_2O H_2/Pt OsO_4

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



10. What is the relationship between the two structures shown below?

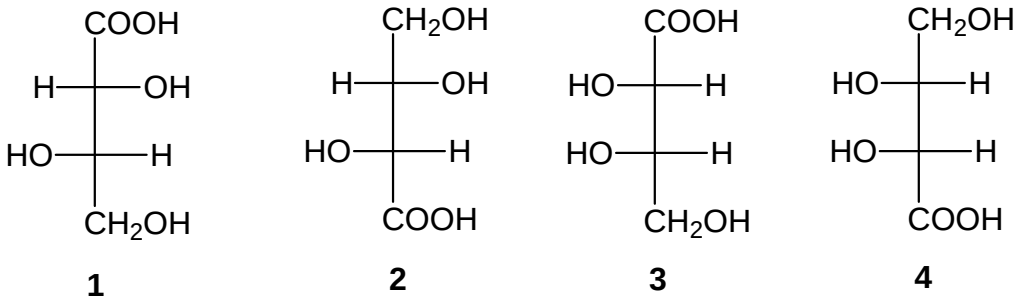




different connectivity

A) Identical
B) Diastereomers
C) Constitutional isomers
D) Conformers
E) Enantiomers

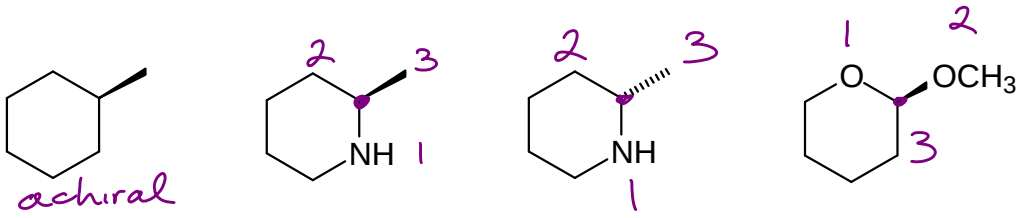
11. Which two of the following compounds rotate plane-polarized light to the same magnitude, but in opposite directions? ∴ enantiomers



A) 1 and 2 ← identical (rotate #2)
B) 3 and 4 ← rotate #4
C) 1 and 3
D) 2 and 3
E) 1 and 4

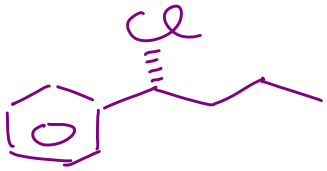
← diastereomers

12. How many of the following molecules contain an *R* stereocentre?



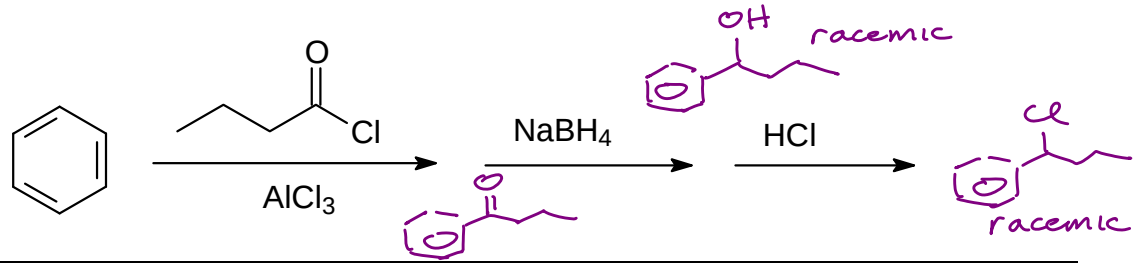
(enantiomer of #2)

A) 1
B) 4
C) None
D) 2
E) 3

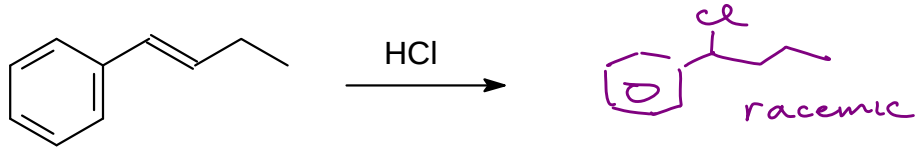


13. The best yield of (*R*)-1-chloro-1-phenylbutane is obtained by which reaction?

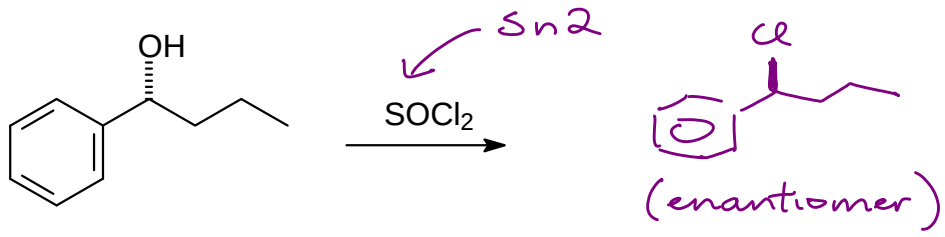
A)



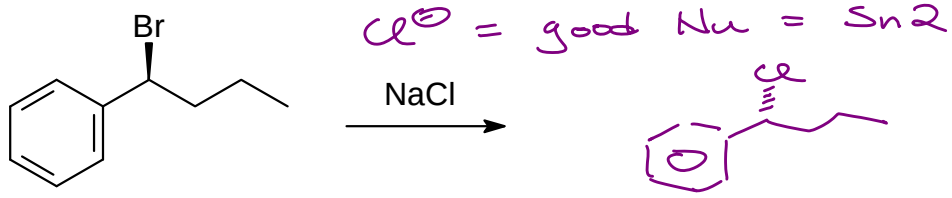
B)



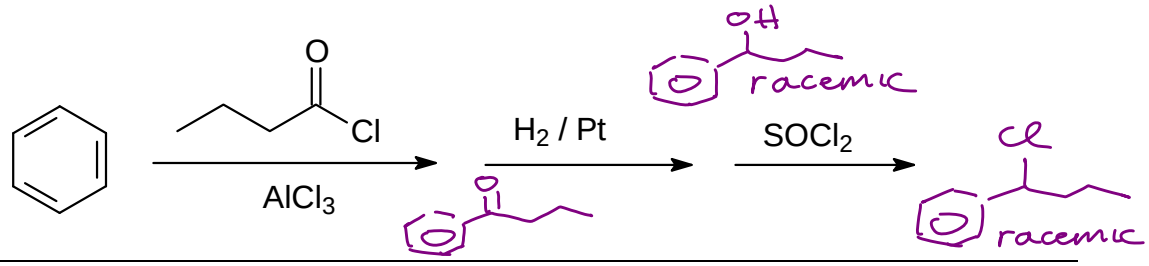
C)



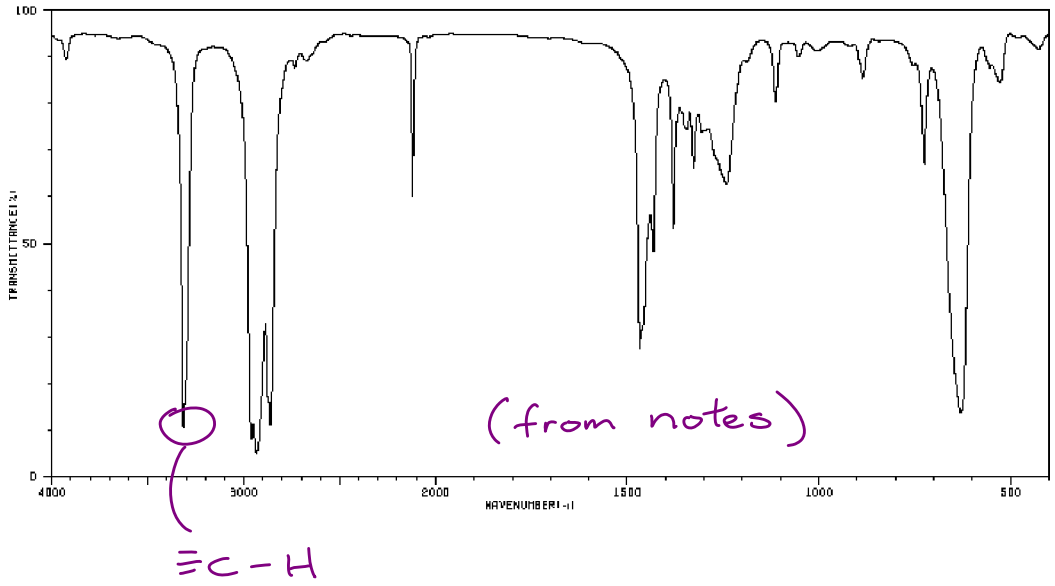
D)



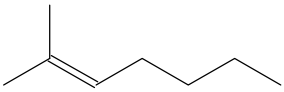
E)

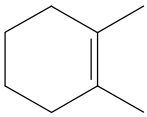


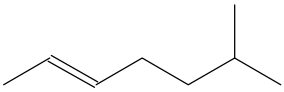
14. What is a possible structure of a compound with the IR spectrum shown below?

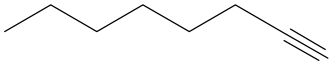


A) 

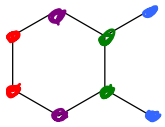
B) 

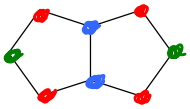
C) 

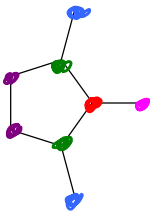
D) 

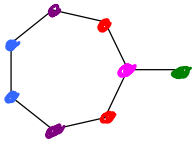
E) 

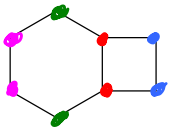
15. Which one of the following has exactly three signals in its ^{13}C-NMR spectrum?

A) 

B) 

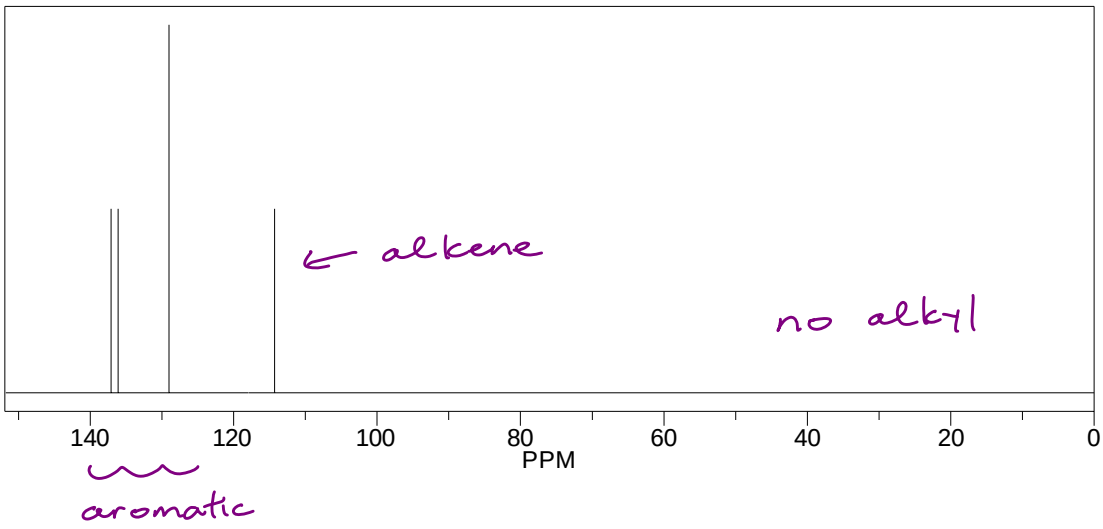
C) 

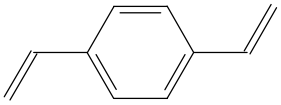
D) 

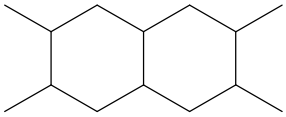
E) 

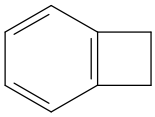
2 reactive π bonds

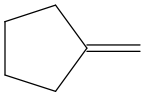
16. An unknown compound reacts with two equivalents of bromine in CCl_4 and has the ^{13}C-NMR spectrum shown below. What could the unknown compound be?

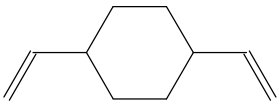


A) 

B) 

C) 

D) 

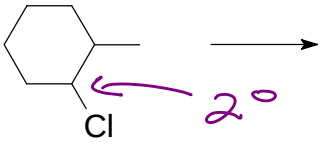
E) 

17. Which one of the following reactions proceeds fastest by an S_N2 mechanism?

good Nu
good LG
space

A) $NaI + CH_3OCH_3 \longrightarrow$ no good leaving group

$I^\ominus$

B) $NaOH +$  $\longrightarrow$

$^\ominus OH$ 2°

C) $(CH_3)_3COK + CH_3CH_2NH_2 \longrightarrow$ ← no good leaving group

$+O^\ominus$ bulky

D) $CH_3NH_2 + CH_3CH_2Cl \longrightarrow$

1°

E) $NaCN + CH_3CH_2Br \longrightarrow$

$^\ominus CN$ 1°

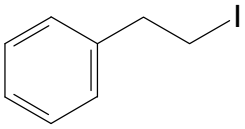
comparing B, D, E, E has the best leaving group (Br^-), is primary, and has the best nucleophile

18. Which one of the following ionizes the fastest when dissolved in methanol?

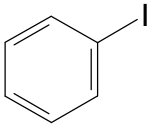
Sn1 or E1

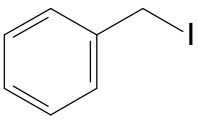
weak nu/base

A) CH_3I

B) 

C) CH_3CH_2I

D) 

E) 

gives most-stable carbocation

19. Rank the following in the order of leaving group ability, from best to worst.

← least-stable

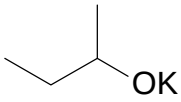
best: $Br^{\ominus}$ worst: $H_2N^{\ominus}$ $HO^{\ominus}$ ↑ most-stable

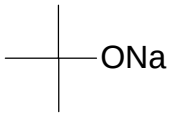
	best	⟶	worst
A)	$HO^{\ominus}$	$Br^{\ominus}$	$H_2N^{\ominus}$
B)	$Br^{\ominus}$	$H_2N^{\ominus}$	$HO^{\ominus}$
C)	$H_2N^{\ominus}$	$Br^{\ominus}$	$HO^{\ominus}$
D)	$Br^{\ominus}$	$HO^{\ominus}$	$H_2N^{\ominus}$
E)	$H_2N^{\ominus}$	$HO^{\ominus}$	$Br^{\ominus}$

20. Which one of the following gives the best yield of an optically active product (or product mixture) when reacted with (*S*)-2-bromopentane?

chiral and not a racemic mixture

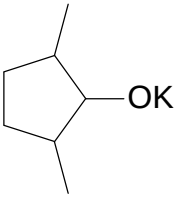
A) CH_3CH_2ONa

B) 

C) 

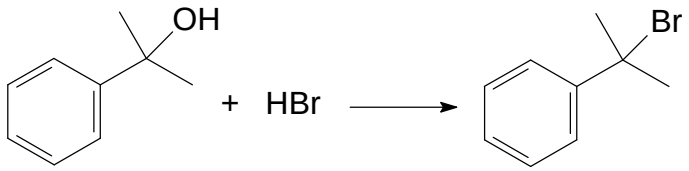
bulky strong base = eliminate

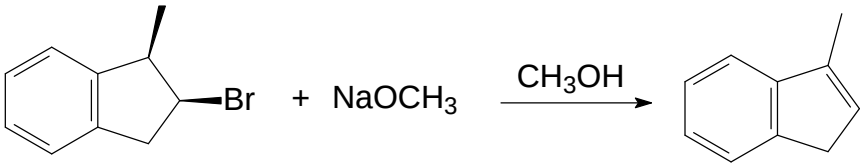
D) CH_3CH_2OH (weak = Sn1)

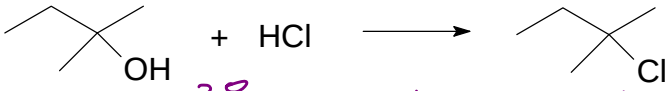
E) 

"A" is the smallest, strong nucleophile → Sn2 most likely

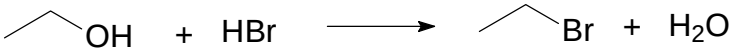
21. Which one of the following does NOT proceed by the mechanism indicated?

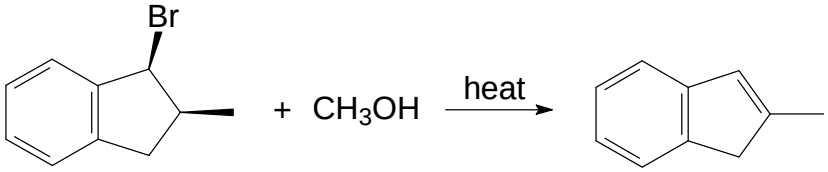
A)  **S_N1**

B)  **E2**

C)  **S_N2**

3° cannot proceed Sn2

D)  **S_N2**

E)  **E1**

22. Rank the following in the order of increasing boiling point (lowest to highest).

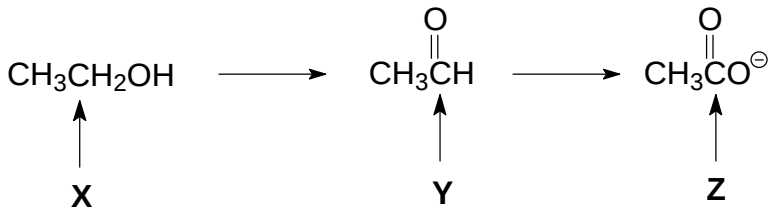
$CH_3CH_2OCH_2CH_3$ **1** $CH_3CH_2CH_2CH_2OH$ **2** $CH_3CH_2CH_2CHO$ **3** CH_3CH_2COOH **4**

	lowest ⟶			highest
A)	**3**	**1**	**2**	**4**
B)	**4**	**2**	**1**	**3**
C)	**1**	**3**	**2**	**4**
D)	**4**	**3**	**1**	**2**
E)	**1**	**4**	**2**	**3**

2 + 4 can H-bond (4 better)

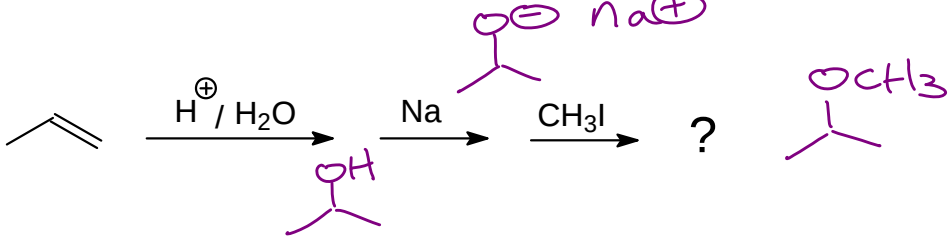
aldehydes more polar than ethers

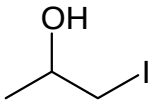
23. Ethanol is metabolized according to the pathway below. What are the oxidation numbers of the indicated carbon atoms?

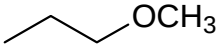


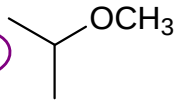
	X	Y	Z
A)	−1	+1	+4
B)	−1	+1	+3
C)	0	+1	+2
D)	+1	0	−1
E)	0	+2	+3

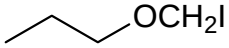
24. What is the major product of the following reaction sequence?

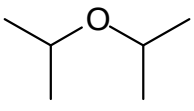


A) 

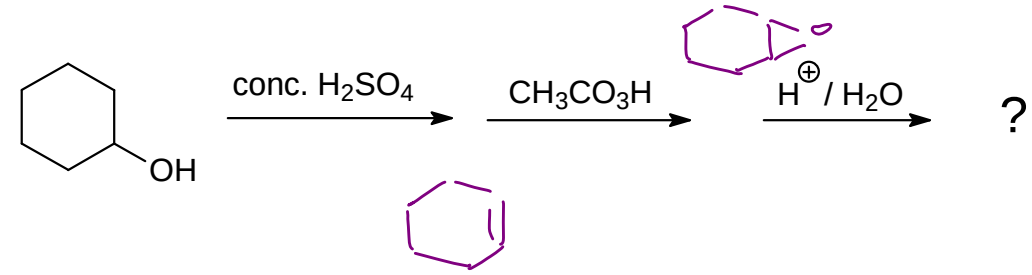
B) 

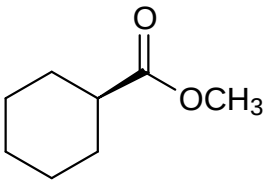
C) 

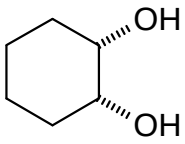
D) 

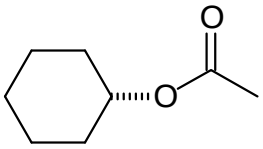
E) 

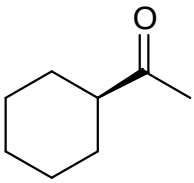
25. What is the major product of the following reaction sequence?

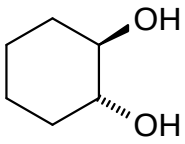


A) 

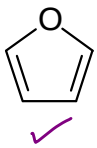
B) 

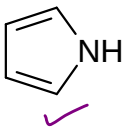
C) 

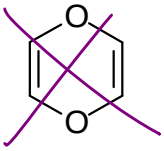
D) 

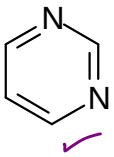
E) 

26. How many of the following molecules are aromatic?



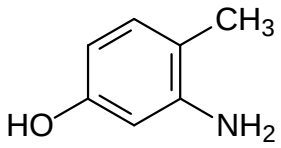






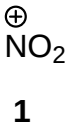
A) None
B) 1
C) 3
D) 2
E) 4

27. What is an incorrect IUPAC name for the compound shown below?

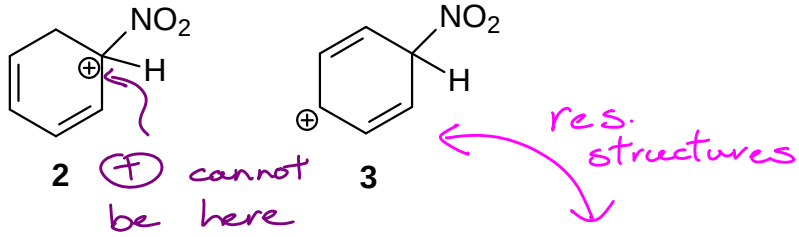


A) 5-hydroxy-2-methylaniline ✓
B) 3-amino-4-methylphenol ✓
C) 2-amino-4-hydroxy-1-methylbenzene ✓
D) 2-amino-4-hydroxytoluene ✓
E) 4-hydroxy-2-methylbenzylamine

28. Which of the following is/are NOT involved in the mechanism for the nitration of benzene?



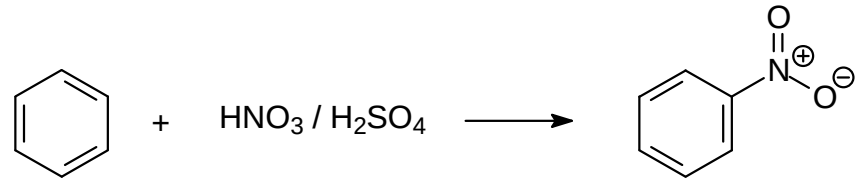
1

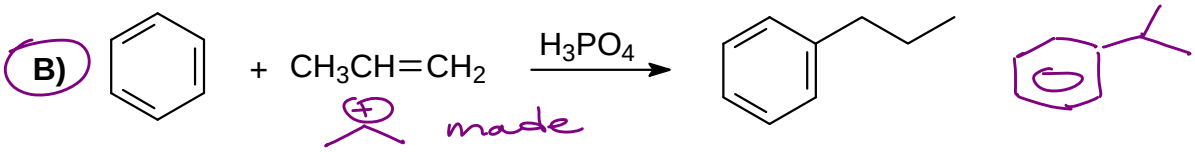


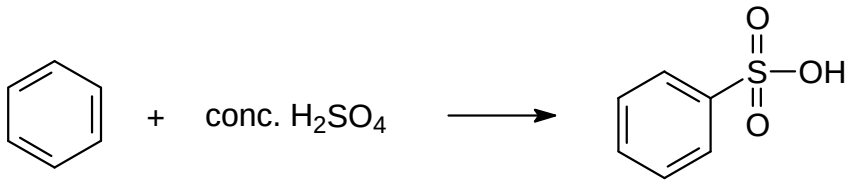
2 **3**

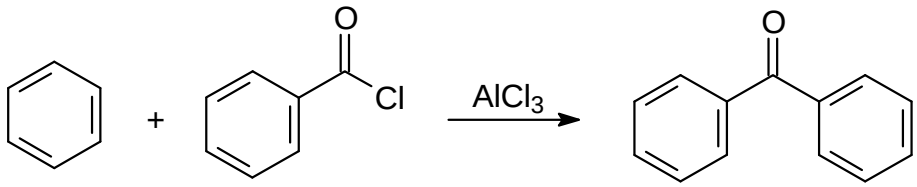
A) None (all are involved)
B) 2 only
C) 2 and 3 only
D) 1 and 2 only
E) All (none are involved)

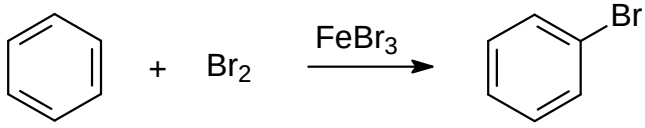
29. Which reaction does NOT give a good yield of the product shown?

A) 

B) 

C) 

D) 

E) 

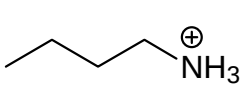
30. How many units of unsaturation are in the DNA base guanine, $C_5H_5N_5O$?

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

- ignore O
∴ $C_5H_5N_5$
- subtract 1 H for each N
∴ C_5H_0
- normally C_5H_{12}

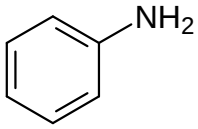
strongest base (least-stable base)

31. Rank the following from the lowest pK_b to the highest pK_b.

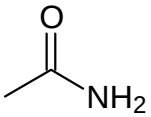


1

no lone pairs



2



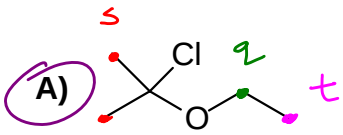
3

amides are more stable than aniline (see example in notes)

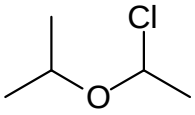
	lowest	⟶	highest
A)	**3**	**1**	**2**
B)	**1**	**2**	**3**
C)	**3**	**2**	**1**
D)	**2**	**3**	**1**
E)	**2**	**1**	**3**

32. The ^{1}H-NMR spectrum of which one of the following molecules contains exactly one singlet, one triplet, and one quartet?

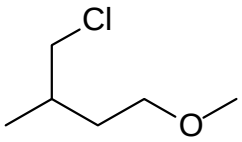
A)



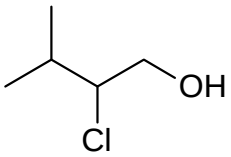
B)



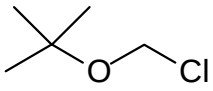
C)



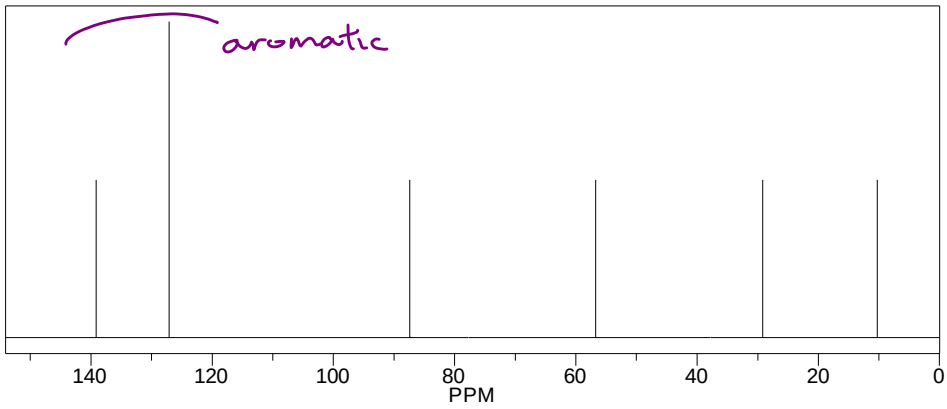
D)

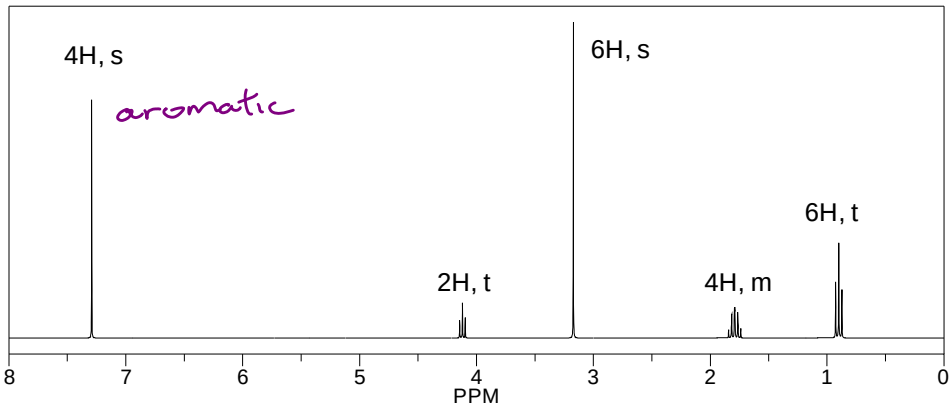


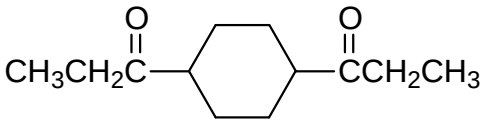
E)

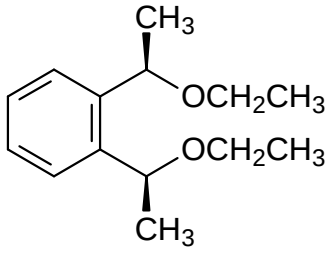


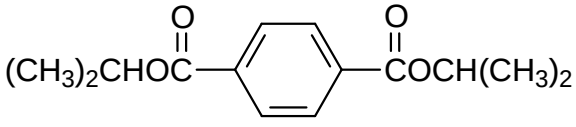
33. Which compound has the ^{13}C- and ^{1}H-NMR spectra shown below?

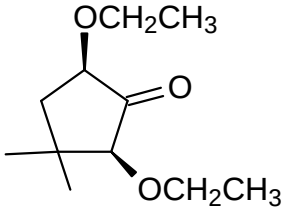


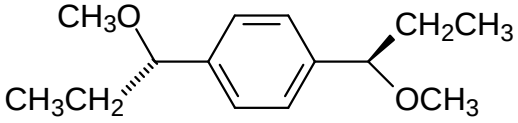


A) 

B) 

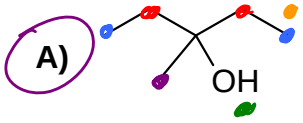
C) 

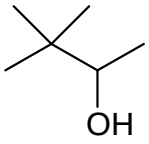
D) 

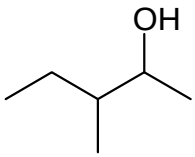
E) 

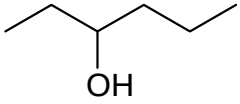
34. An alcohol **X**, $C_6H_{14}O$, undergoes acid-catalyzed dehydration to give an alkene, C_6H_{12}. The ^{1}H-NMR spectrum of **X** shows peaks at δ (ppm) 1.48 (4H, q), 1.38 (1H, s), 1.12 (3H, s), and 0.89 (6H, t). The ^{13}C-NMR spectrum of **X** shows peaks at δ (ppm) 73.0, 33.7, 25.9, and 8.2. What is the structure of alcohol **X**?

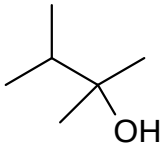
from textbook

A) 

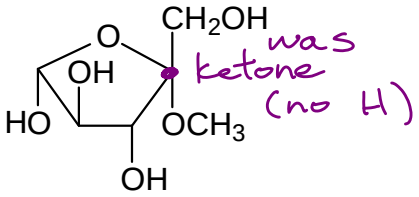
B) 

C) 

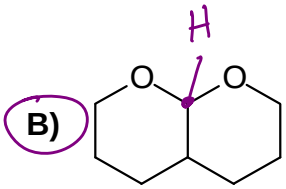
D) 

E) 

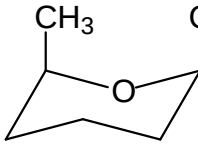
35. Which one of the following is an acetal derived from an aldehyde?

A) 

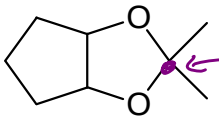
was ketone (no H)

B) 

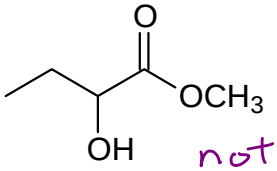
was aldehyde

C) 

H
hemiacetal of aldehyde

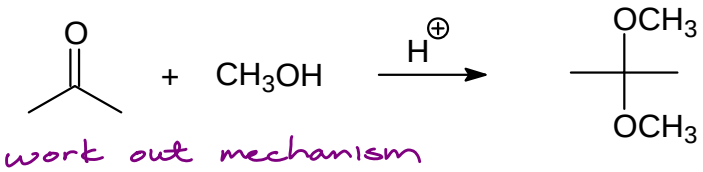
D) 

acetal of ketone

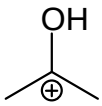
E) 

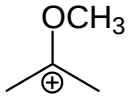
not an acetal

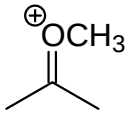
36. Which of the following is NOT involved in the mechanism for this reaction?



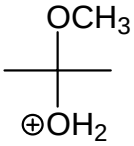
work out mechanism

A) 

B) 

C) 

D) 

E) 

37. (*S*)-2-methylbutanal was placed in a basic solution. After a period of time, the solution became optically inactive. What happened?

racemic mixture

A) None of the other statements can explain the observations

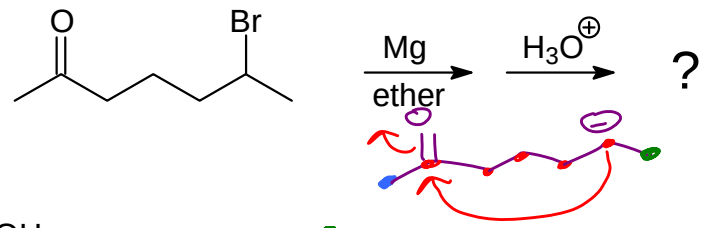
B) Oxidation of the aldehyde to a carboxylic acid occurred

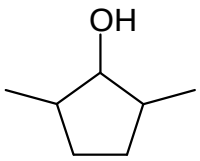
C) Keto-enol tautomerism occurred

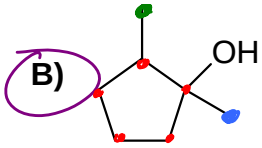
D) Reduction of the aldehyde produced an alcohol

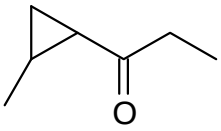
E) Decarboxylation of the aldehyde occurred

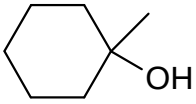
38. What is the major product of the following reaction sequence?



A) 

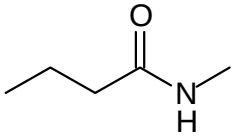
B) 

C) 

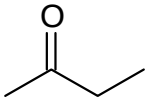
E) 

39. Which two organic reagents can be used to prepare *sec*-butyl methyl amine via a *reductive amination* reaction?

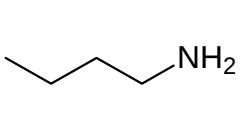
C=O + amine, then reduction of imine

A) 

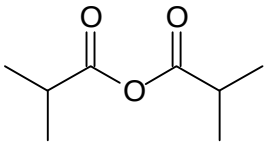
+ CH_3OH

B) 

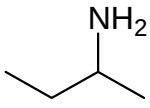
+ CH_3NH_2

C) 

+

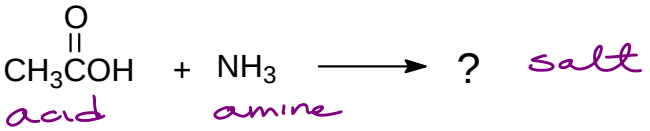
D) 

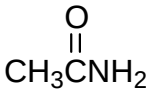
+ CH_3NH_2

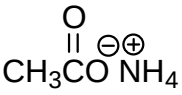
E) 

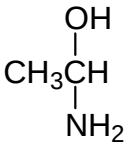
+ CH_3I

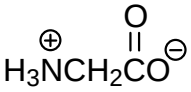
40. What is the product of the following reaction?

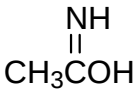


A) 

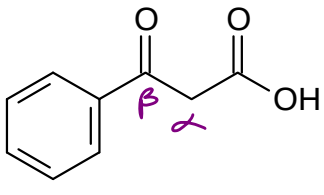
B) 

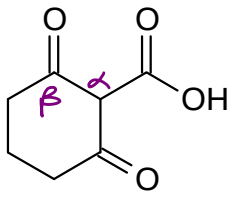
C) 

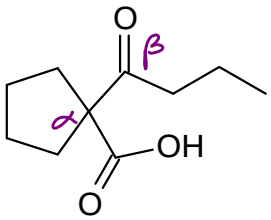
D) 

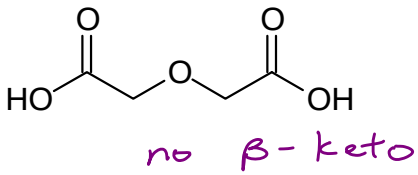
E) 

41. How many of the following compounds release carbon dioxide when heated?



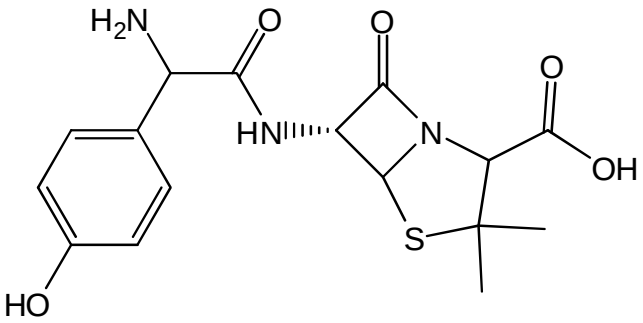






A) 3
B) 2
C) 1
D) 4
E) None

42. Which statement(s) is/are correct about the antibiotic amoxicillin?



1. It contains a β lactone (cyclic ester) ✗
2. It has exactly 9 units of unsaturation 6 π + 3 rings ✓
3. The aromatic ring is *para*-disubstituted ✓
4. It contains exactly 3 primary, sp^3-hybridized carbons only 2 ✗

A) All statements are correct
B) 1 and 3 only
C) 1 and 2 only
D) 2 and 3 only
E) 2, 3, and 4 only

43. Which one of the following reacts most slowly with aqueous NaOH?

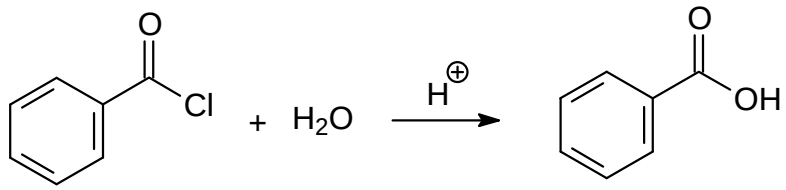
A) CH_3COH **B)** CH_3COCH_3 **C)** CH_3COCCH_3

D) CH_3CCl **E)** $CH_3CN(CH_3)_2$

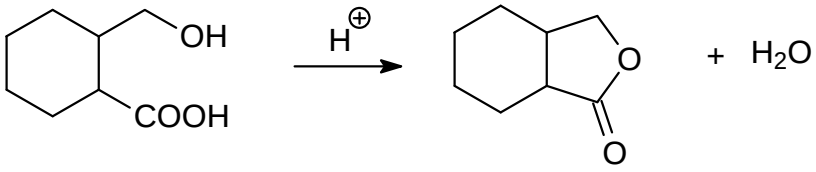
amide = least-reactive acid derivative

44. Which reaction does NOT give a good yield of the product shown?

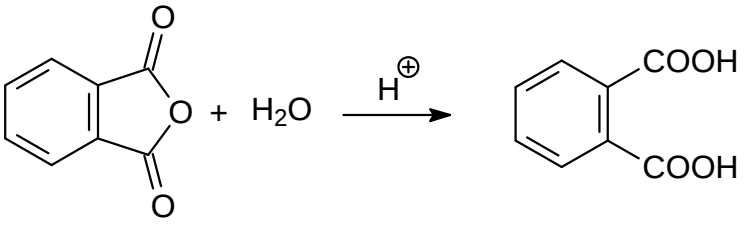
A)



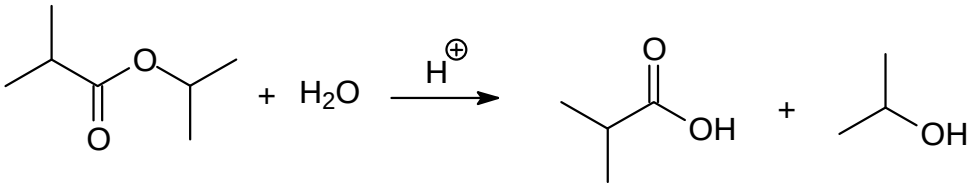
B)



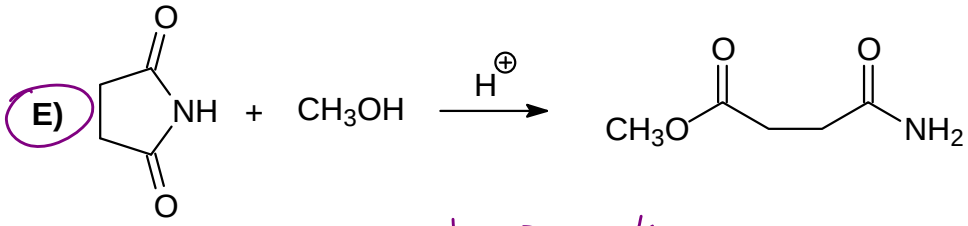
C)



D)



E)



amide → ester

45. Which of the following reagents gives a positive visual test for an alkene?

Br_2	$KMnO_4$	HBr
1	**2**	**3**

red/brown ppt formed

A) 1 only
B) 3 only
C) 1 and 2 only
D) 2 and 3 only
E) 2 only

46. In organic chemistry, what does the term *salting out* refer to?

A) The addition of NaCl to reduce the solubility of an organic compound in water
B) The commercial process used to isolate sea salt by evaporating salt water
C) The removal of HCl by neutralization with NaOH, forming NaCl
D) The precipitation of the salt of an organic acid
E) The distillation of a mixture, leaving the salt in the distillation flask and collecting the salt-free distillate

47. Which statement(s) is/are correct about the acetone used in the *sodium iodide in acetone test* for alkyl halides? Sn2 test

1. It is a polar, aprotic solvent ✓
2. Sodium iodide is soluble in acetone ✓
3. Sodium chloride and sodium bromide are both insoluble in acetone ✓

(ppt = positive test)

A) 2 and 3 only
B) 1 only
C) 1 and 3 only
D) All statements are correct
E) 1 and 2 only

48. In the *silver nitrate in ethanol test* for alkyl halides, what is the rate-determining step of the reaction that occurs in a positive test? Sn1

A) Oxidation of the alkyl halide by Ag^+

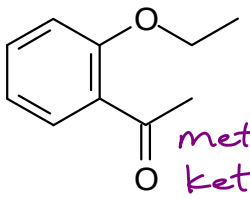
B) Dissociation of $AgNO_3$

C) Reaction of Ag^+ with Cl^-

D) Reaction of the carbocation with NO_3^-

E) Ionization of the alkyl halide

49. What are the expected Tollens', iodoform, and ferric chloride test results for the compound shown?



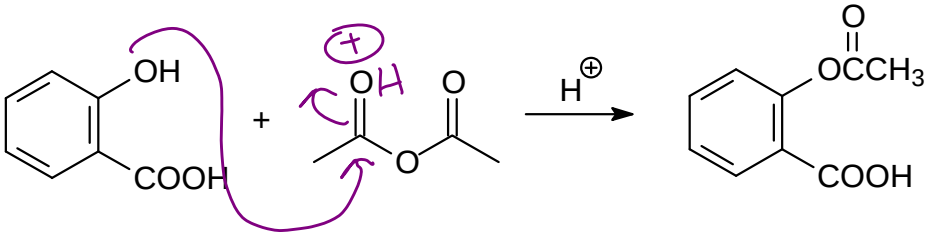
methyl ketone

	Tollens'	Iodoform	Ferric chloride
A)	positive	negative	negative
B)	positive	positive	positive
C)	negative	positive	positive
D)	negative	positive	negative
E)	positive	positive	negative

no aldehyde

no phenol

50. Why was the acetylation of salicylic acid performed under acidic conditions?



A) The acid makes acetic anhydride a more reactive electrophile

B) The acid adds to the aromatic ring to make it more electrophilic

C) The acid neutrailizes any NaOH present in the reaction mixture

D) The acid makes the phenolic OH group of salicylic acid a better nucleophile

E) The acid makes the phenolic OH group of salicylic acid a better leaving group