

Please read and sign the Honor Code statement below:

I pledge that on my honor, as a University of Colorado at Boulder student, I have neither given nor received unauthorized assistance on this exam.

Signature

General Instructions: There are 13 pages and 19 questions, including this cover sheet. Be sure you have them all. Read each question carefully so that you know exactly what is being asked and what you need to write or draw. Your work on scratch pages will not be graded, so be sure everything you want graded is written on the exam itself and that your answers to the multiple choice questions are correctly bubbled in on the Scantron.

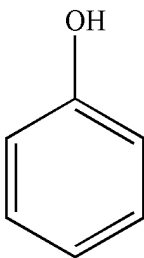
Each multiple choice question (1-16) is worth **3 points** and has **only one correct answer**. Good luck!

PERIODIC CHART OF THE ELEMENTS

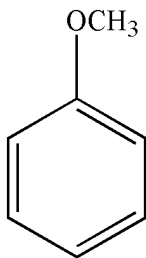
IA	IIA	IIIB	IVB	VB	VIB	VIIIB	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	INERT GASES		
1 H 1.00797														1 H 1.00797	2 He 4.0026		
3 Li 6.939	4 Be 9.0122										5 B 10.811	6 C 12.0112	7 N 14.0067	8 O 15.9994	9 F 18.9984	10 Ne 20.183	
11 Na 22.9898	12 Mg 24.312										13 Al 26.9815	14 Si 28.086	15 P 30.9738	16 S 32.064	17 Cl 35.453	18 Ar 39.948	
19 K 39.102	20 Ca 40.08	21 Sc 44.956	22 Ti 47.90	23 V 50.942	24 Cr 51.996	25 Mn 54.9380	26 Fe 55.847	27 Co 58.9332	28 Ni 58.71	29 Cu 63.54	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.9216	34 Se 78.96	35 Br 79.909	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.905	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc [99]	44 Ru 101.07	45 Rh 102.905	46 Pd 106.4	47 Ag 107.870	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.904	54 Xe 131.30
55 Cs 132.905	56 Ba 137.34	*57 La 138.91	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 196.967	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.980	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	+89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 ? (271)	111 ? (272)	112 ? (277)						

Circle the single best answer to each multiple choice question (1-16). (3 pts each)

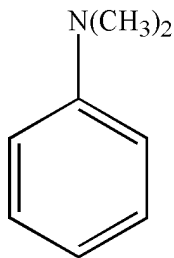
1. Which of the following compounds is **deactivated** relative to benzene?



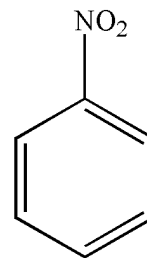
I



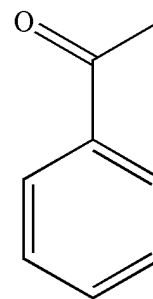
II



III



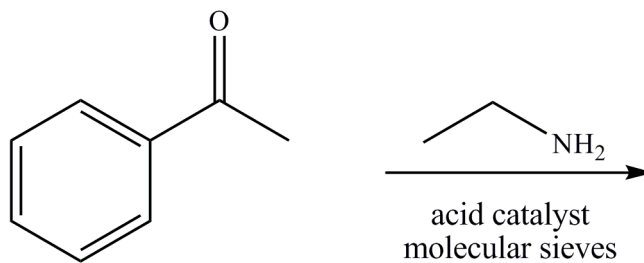
IV



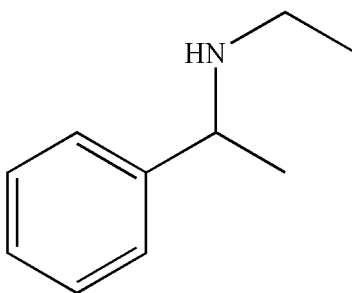
V

- a. I
 - b. I and II
 - c. III
 - d. IV
 - e. IV and V
2. Carbonyl compounds react with organometallic reagents like Grignard and organolithium reagents. Which of the following statements about these reactions is **true**?
- a. Ketones are less reactive than aldehydes.
 - b. Ketones are more reactive than esters.
 - c. Aldehydes are less reactive than esters.
 - d. Aldehydes, ketones, and esters have similar reactivity.
 - e. Esters react faster than ketones.

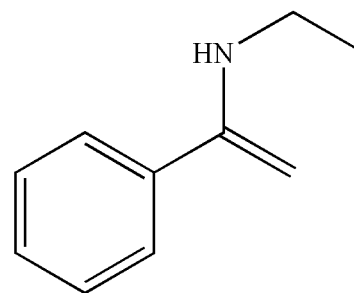
3. Which of the following is the major product of the reaction conditions shown?



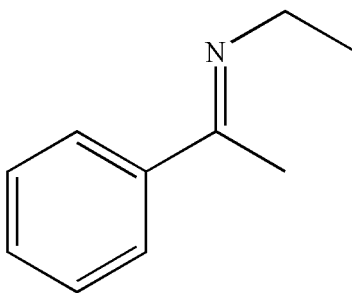
a.



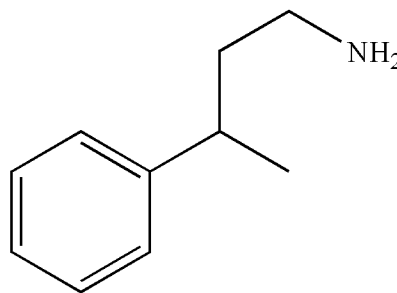
b.



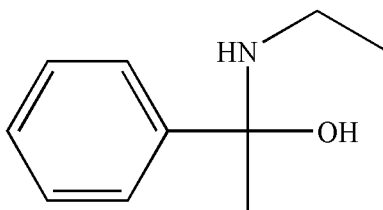
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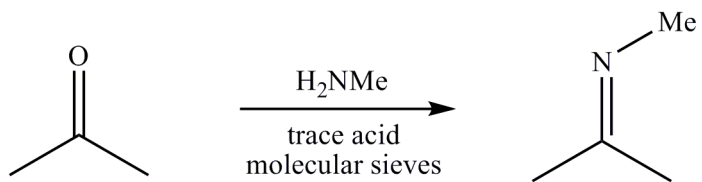
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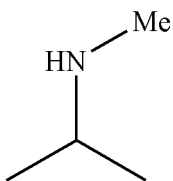
e.



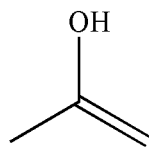
4. Which of these structures is a mechanistic intermediate in the following transformation?



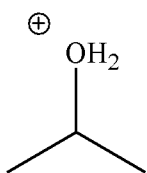
a.



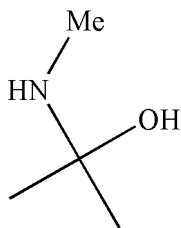
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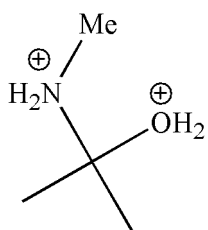
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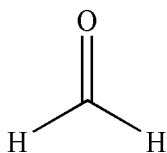


e.

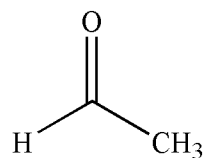


5. Which of the following compounds, when placed in water, do you expect to have the *least* amount of hydrate present at equilibrium?

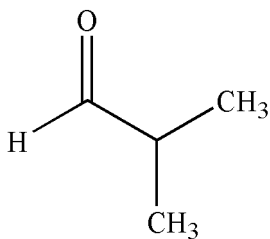
a.



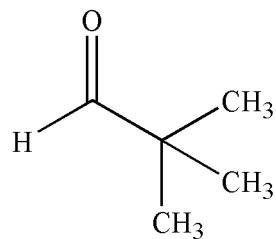
b.



c.



d.



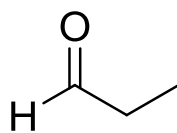
e. All carbonyl compounds have the same amounts of hydrate at equilibrium.

6. Which of the following compounds requires two equivalents of a Grignard reagent or organolithium for complete reaction?

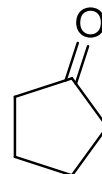
a.



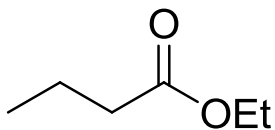
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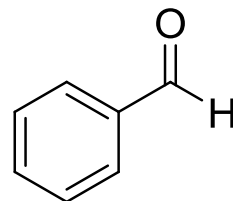
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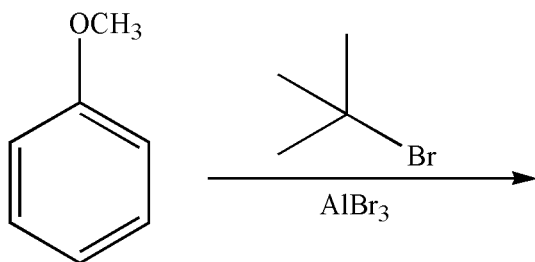
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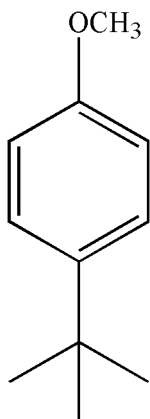
e.



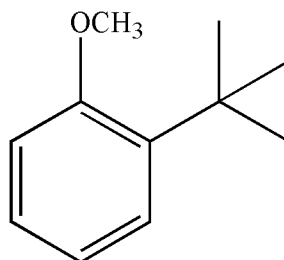
7. Which of the following compounds is the major product of this reaction?



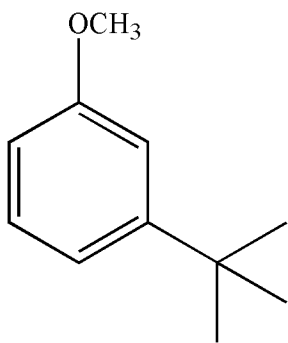
a.



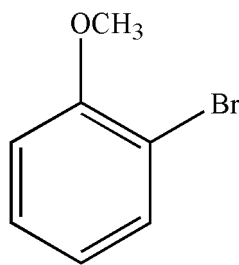
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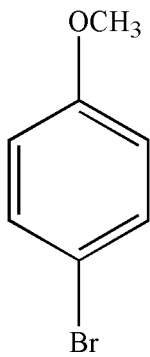
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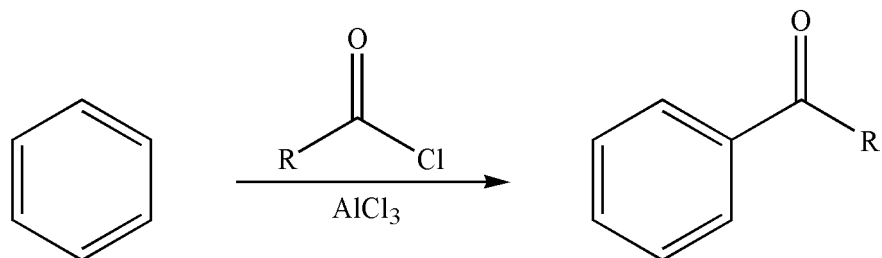
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e.

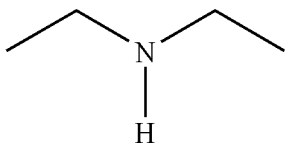


8. Why is at least one equivalent of AlCl_3 required for the transformation shown?

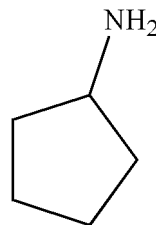


- a. The product rearranges unless extra AlCl_3 is present.
 - b. Both benzene and the acid chloride form complexes with the AlCl_3 .
 - c. The product forms a complex with the AlCl_3 , removing it from the reaction and preventing it from acting as a catalyst.
 - d. The AlCl_3 is needed to produce the acid chloride during the course of the reaction.
9. Which of the following compounds cannot be used to form an imine?

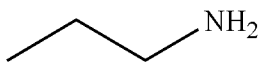
a.



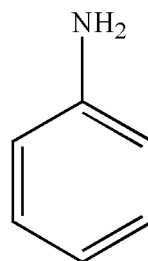
b.



c.



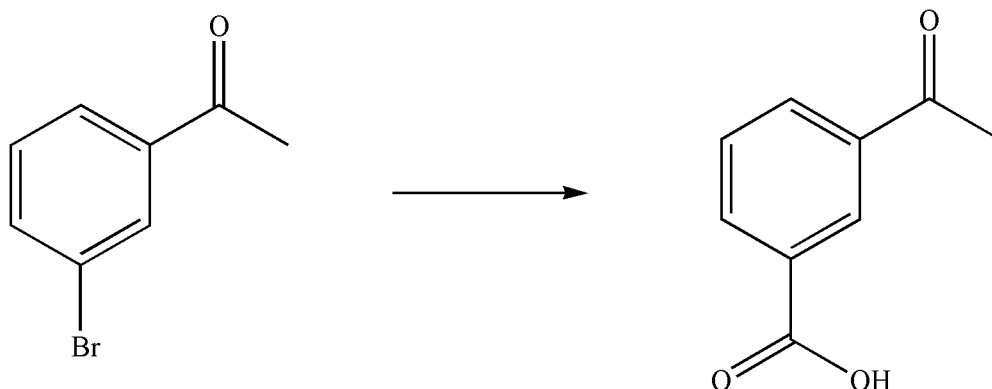
d.

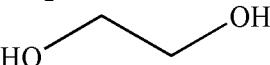


e.

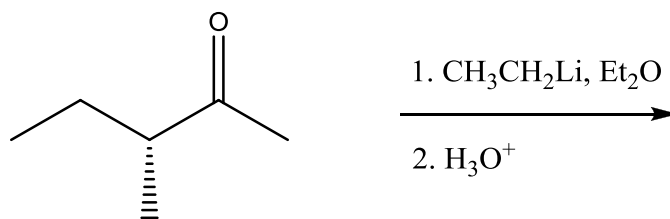


10. In the multistep synthesis shown, what would be the *first* step?



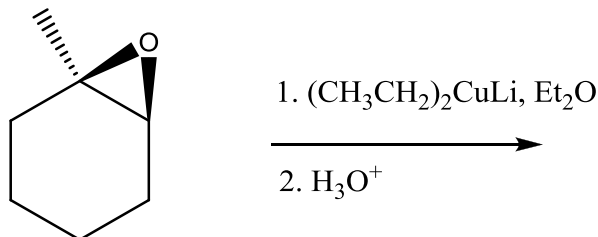
- a. Mg, ether
- b. CO₂
- c.  and acid catalyst and molecular sieves
- d. H₃O⁺
- e. KMnO₄

11. What will be the stereochemical outcome of this reaction?



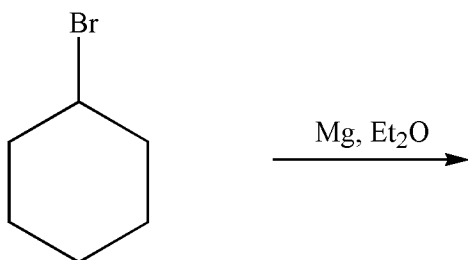
- a. Enantiomers, equal amounts
- b. Enantiomers, unequal amounts
- c. Diastereomers, equal amounts
- d. Diastereomers, unequal amounts
- e. A single chiral product

12. What will be the stereochemical outcome of the following reaction?

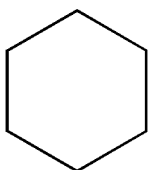


- a. Enantiomers, equal amounts
 - b. Enantiomers, unequal amounts
 - c. Diastereomers, equal amounts
 - d. Diastereomers, unequal amounts
 - e. A single chiral product
13. Reactions where imines or enamines are formed must be run at carefully controlled pH. If the pH of the reaction mixture is less than 5, no reaction can occur. Which of the following statements provides the best explanation for this observation?
- a. If the reaction pH is too low, the carbonyl oxygen cannot be protonated.
 - b. If the reaction pH is too low, the nitrogen atom in the amine reactant will become protonated, and the amine can no longer act as a nucleophile.
 - c. If the reaction pH is too low, it is no longer possible to control the equilibrium position.
 - d. If the reaction pH is too low, the amine cannot be protonated and the reaction cannot proceed.
 - e. None of these statements explains the observed failure of the reaction.
14. What is the purpose of including molecular sieves in an acetal formation reaction?
- a. To provide a constant source of water for the reaction.
 - b. To regenerate the acid catalyst in the reaction.
 - c. To remove water from the reaction mixture as it is formed.
 - d. To remove the carbonyl compound (ketone or aldehyde) from the reaction mixture as it is formed.
 - e. None of these statements correctly describes the purpose of including molecular sieves in an acetal formation reaction.
15. Which of the following statements about organolithium reagents is *false*?
- a. They are strongly basic.
 - b. They are strongly acidic.
 - c. They are formed from the reaction of an alkyl halide and lithium metal.
 - d. Methyl lithium reacts with water to produce methane.
 - e. Organolithium reagents cannot be used with acidic solvents.

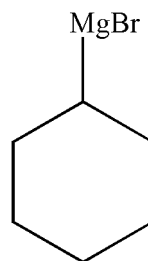
16. Predict the product of the following reaction:



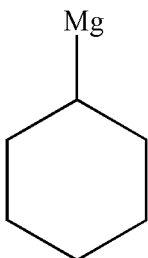
a.



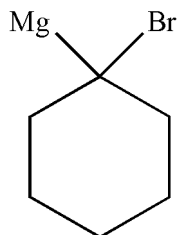
b.



c.

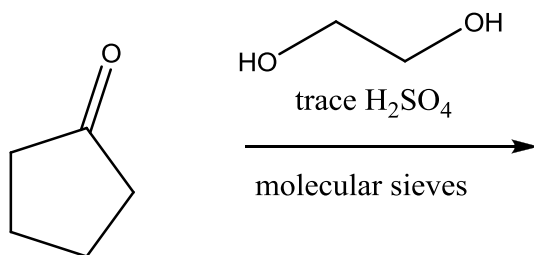


d.

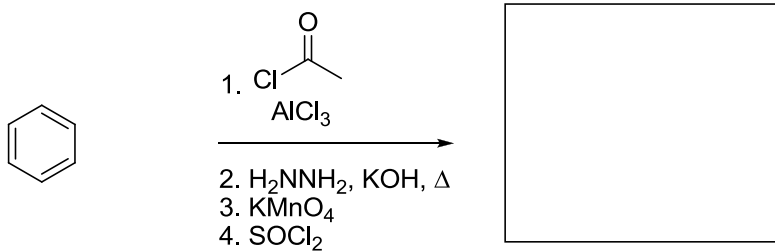
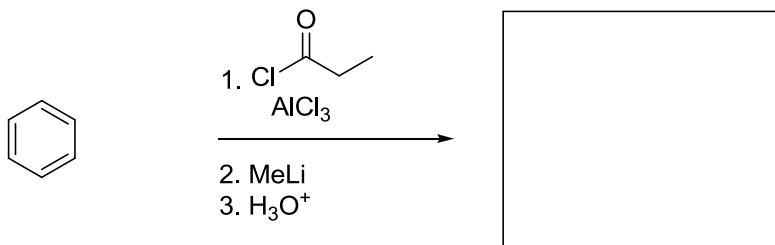
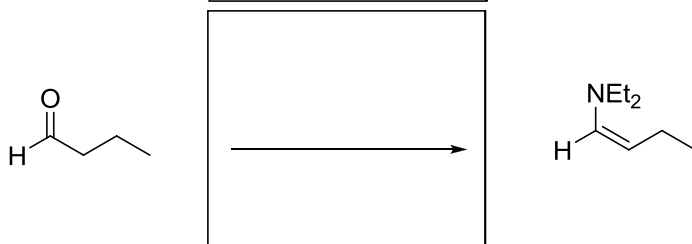
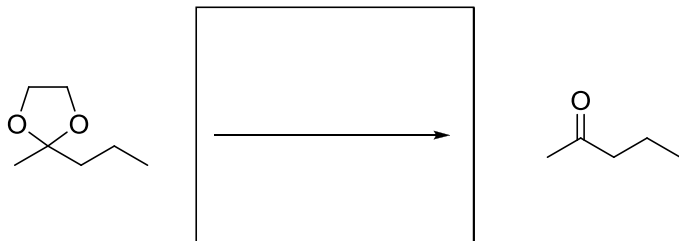
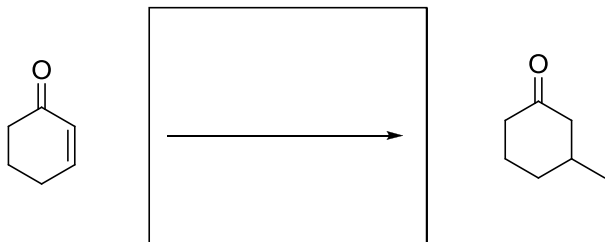


e. None of these structures is the product of the reaction.

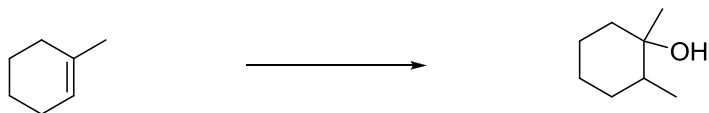
17. Predict the major organic product of the following reaction and provide a mechanism to show how it is formed. Include all curved arrows, intermediates, lone pairs of electrons, and non-zero formal charges for full credit. (15 pts)



18. Predict the products or supply the missing reagents for the following reactions or reaction sequences. You do not need to show stereochemistry. (15 pts)



19. Design a multi-step synthesis for each of the following transformations. Note that for the first problem, you must design **two different multi-step syntheses**. Show the reagents needed for each step and the product of each step. Do not draw any mechanisms. Do not provide a list of reagents without showing the product of each step. (22 pts)



Synthesis 1:

Synthesis 2:

