

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 10 pages and 17 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.

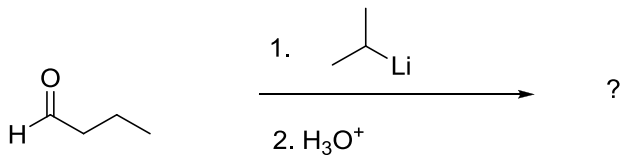
Each multiple choice question (1-14) is worth **3 points** and has **only one correct answer**. Good luck!

**PERIODIC CHART OF THE ELEMENTS**

IA	IIA	IIIB	IVB	VB	VIB	VIIIB	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA	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 (268)	110 ? (271)	111 ? (272)	112 ? (277)						

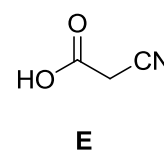
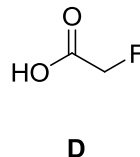
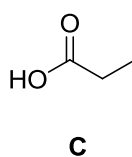
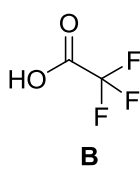
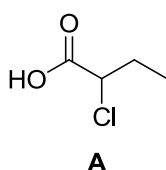
Select the single best answer to each multiple choice question (1-14). (3 pts each)

1. When the reaction shown here occurs, the product(s) will be:

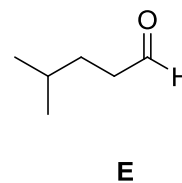
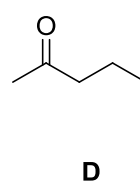
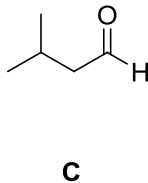
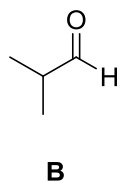
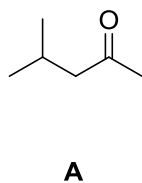
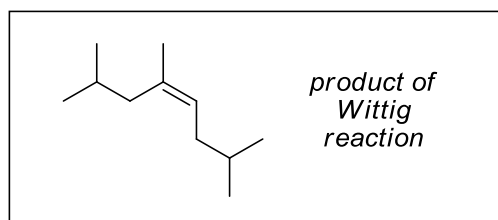


- a. a single achiral molecule
- b. a racemic mixture
- c. an unequal mixture of enantiomers
- d. an equal mixture of diastereomers
- e. an unequal mixture of diastereomers

2. Which of the following is the **least** acidic species?



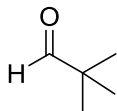
3. A Wittig reaction was performed and resulted in the product shown. What is the structure of the carbonyl compound that was used to synthesize the ylide in this reaction? (The correct answer is the one that uses the most efficient possible synthetic route.)



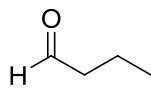
4. Which of the following aldehydes do you expect to have the *smallest* value of  $K_{\text{hydration}}$ ?



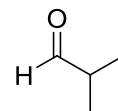
A



B



C

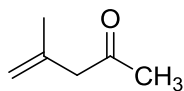
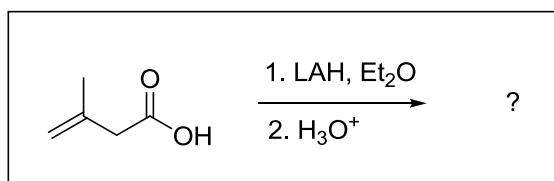


D

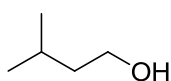


E

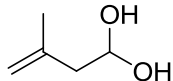
5. What is the major organic product of the following reaction?



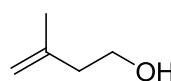
A



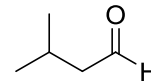
B



C

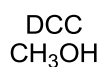
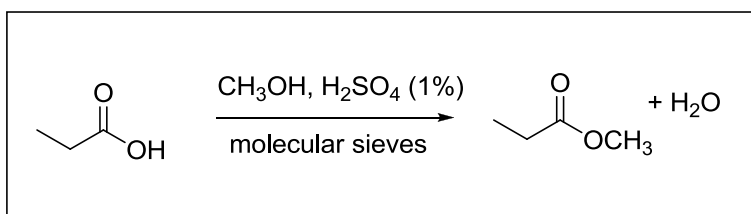


D



E

6. A carboxylic acid was esterified in the manner shown below (in the box). Which of the methods listed could also be used to synthesize this ester?



A



B



C

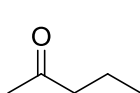
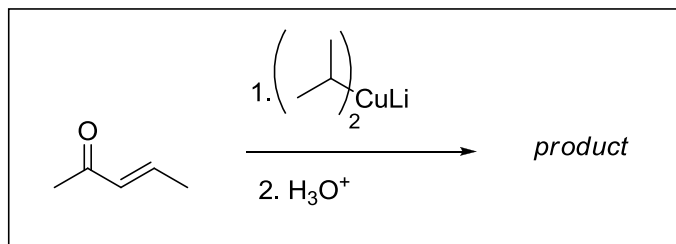
All of these  
methods  
would work

D

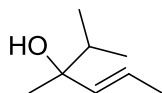
None of  
these methods  
would work

E

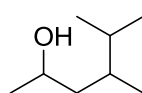
7. What is the product of the reaction conditions shown?



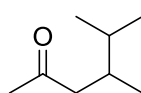
A



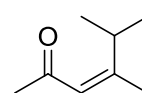
B



C

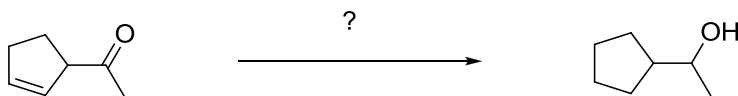


D



E

8. Which reagent would you use to accomplish this transformation?



- a. LAH
- b.  $\text{NaBH}_4$
- c. NaH
- d. Raney Ni/ $\text{H}_2$
- e. Either "a" or "b"

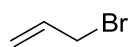
9. Which of the alkyl halides shown would be the least appropriate choice to use as a precursor to an ylide for a Wittig reaction?



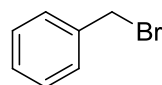
A



B



C



D

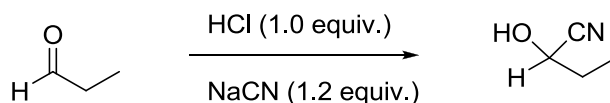
All of these  
can be made  
into ylides  
with no problem

E

10. Which of these statements is false?

- a. LAH is a stronger reducing agent than  $\text{NaBH}_4$ .
- b. The Al-H bond is longer than the B-H bond.
- c. Na coordinates (attaches) more tightly to O than Li.
- d.  $\text{NaBH}_4$  can be used with protic solvents like water and alcohols.
- e. LAH can be used to reduce carboxylic acids.

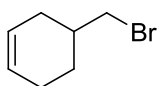
11. Think about the mechanism of cyanohydrin formation that occurs under the following conditions:



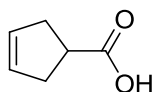
Which of these statements is *true*?

- a. The carbonyl oxygen is protonated by HCN.
- b. The carbonyl oxygen is protonated by HCl.
- c. The alkoxide intermediate is protonated by HCN.
- d. The alkoxide intermediate is protonated by HCl.
- e. There is no proton transfer step in this mechanism.

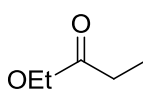
12. Compound **X** can be used to form an ylide. It can also be reacted with a carboxylate ion to produce an ester. When treated with ozone, it gives no reaction, but when treated with bromine and  $\text{FeBr}_3$  a reaction occurs. Which of these structures is compound **X** ?



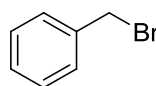
**A**



**B**



**C**

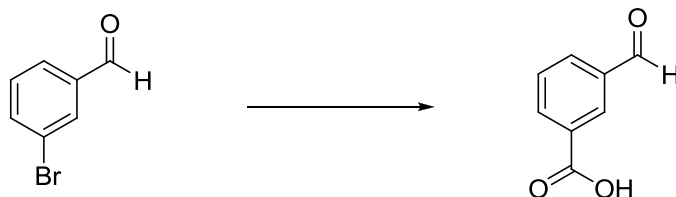


**D**

None of these is Compound X

**E**

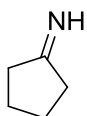
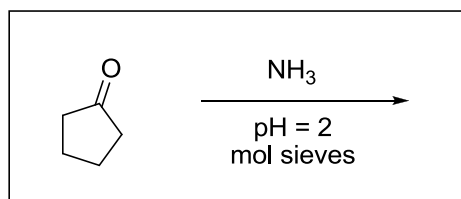
13. Consider the following transformation:



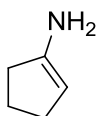
Which of the following multi-step synthetic pathways would successfully accomplish this transformation? (Assume appropriate solvents and aqueous workups where not explicitly written.)

1.  $\text{KMnO}_4$   
2. Mg  
3.  $\text{CO}_2$ , then  $\text{H}_3\text{O}^+$   
4. 0.5 equiv LAH, then  $\text{H}_3\text{O}^+$
1. Clemmensen or Wolff-Kishner reduction  
2. Mg  
3.  $\text{CO}_2$ , then  $\text{H}_3\text{O}^+$   
4.  $\text{MnO}_2$
1.  $\text{CH}_3\text{OH}$ , trace  $\text{H}_2\text{SO}_4$ , molecular sieves  
2. Mg  
3.  $\text{CO}_2$ , then  $\text{H}_3\text{O}^+$   
4.  $\text{H}_3\text{O}^+$
1. LAH, then  $\text{H}_3\text{O}^+$   
2. Mg  
3.  $\text{CO}_2$ , then  $\text{H}_3\text{O}^+$   
4.  $\text{MnO}_2$
- None of these pathways would work.

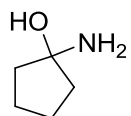
14. What is the most likely result of the reaction conditions shown?



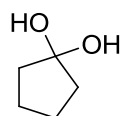
**A**



**B**



**C**

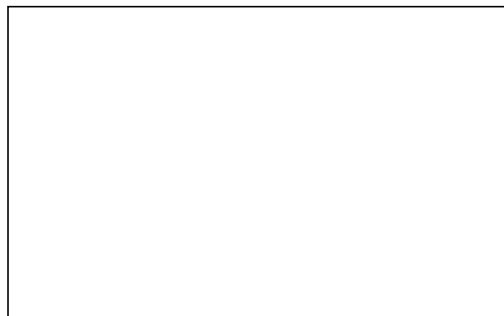
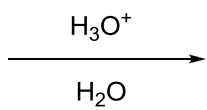
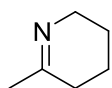


**D**

No reaction

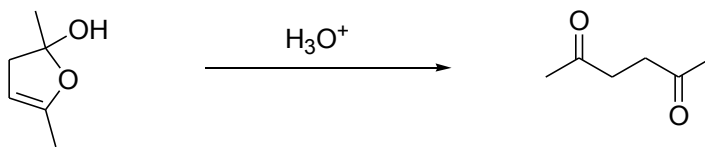
**E**

15. Predict the major organic product of the conditions shown and draw a mechanism to rationalize its formation. Include all curved arrows, intermediates, necessary electrons, and nonzero formal charges for full credit. (15 pts)





16. Draw a mechanism to illustrate the transformation shown. Include all curved arrows, intermediates, necessary electrons and nonzero formal charges for full credit. (15 pts)



17. Design a multi-step synthesis for each of the following transformations. 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. (18 pts)

