

Name: \_\_\_\_\_ Student ID #: \_\_\_\_\_

**CIRCLE YOUR RECITATION SECTION and T.A.:**

- |     |         |     |         |
|-----|---------|-----|---------|
| 211 | Jessica | 221 | Aaron   |
| 212 | Lance   | 222 | Matthew |
| 213 | Tianyi  | 223 | Ethan   |
| 214 | Paula   | 224 | Dylan   |
| 215 | Brendan | 225 | Brendan |

**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 5 pages of questions. Be sure you have them all. Read each question carefully so that you know exactly what is being asked. Good luck!

1A    2A    3A    4A    5A    6A    7A    8A

hydrogen 1 <b>H</b> 1.0079																	helium 2 <b>He</b> 4.0026	
lithium 3 <b>Li</b> 6.941	beryllium 4 <b>Be</b> 9.0122											boron 5 <b>B</b> 10.811	carbon 6 <b>C</b> 12.011	nitrogen 7 <b>N</b> 14.007	oxygen 8 <b>O</b> 15.999	fluorine 9 <b>F</b> 18.998	neon 10 <b>Ne</b> 20.180	
sodium 11 <b>Na</b> 22.990	magnesium 12 <b>Mg</b> 24.305											aluminum 13 <b>Al</b> 26.982	silicon 14 <b>Si</b> 28.086	phosphorus 15 <b>P</b> 30.974	sulfur 16 <b>S</b> 32.065	chlorine 17 <b>Cl</b> 35.453	argon 18 <b>Ar</b> 39.948	
potassium 19 <b>K</b> 39.098	calcium 20 <b>Ca</b> 40.078	scandium 21 <b>Sc</b> 44.956	titanium 22 <b>Ti</b> 47.867	vanadium 23 <b>V</b> 50.942	chromium 24 <b>Cr</b> 51.996	manganese 25 <b>Mn</b> 54.938	iron 26 <b>Fe</b> 55.845	cobalt 27 <b>Co</b> 58.933	nickel 28 <b>Ni</b> 58.693	copper 29 <b>Cu</b> 63.546	zinc 30 <b>Zn</b> 65.39	gallium 31 <b>Ga</b> 69.723	germanium 32 <b>Ge</b> 72.61	arsenic 33 <b>As</b> 74.922	selecnium 34 <b>Se</b> 78.96	bromine 35 <b>Br</b> 79.904	krypton 36 <b>Kr</b> 83.80	
rubidium 37 <b>Rb</b> 85.468	strontium 38 <b>Sr</b> 87.62	yttrium 39 <b>Y</b> 88.906	zirconium 40 <b>Zr</b> 91.224	niobium 41 <b>Nb</b> 92.906	molybdenum 42 <b>Mo</b> 95.94	technetium 43 <b>Tc</b> [98]	ruthenium 44 <b>Ru</b> 101.07	rhodium 45 <b>Rh</b> 102.91	palladium 46 <b>Pd</b> 106.42	silver 47 <b>Ag</b> 107.87	cadmium 48 <b>Cd</b> 112.41	indium 49 <b>In</b> 114.82	tin 50 <b>Sn</b> 118.71	antimony 51 <b>Sb</b> 121.76	tellurium 52 <b>Te</b> 127.60	iodine 53 <b>I</b> 126.90	xenon 54 <b>Xe</b> 131.29	
caesium 55 <b>Cs</b> 132.91	barium 56 <b>Ba</b> 137.33	57-70 * Lu	lutetium 71 <b>Lu</b> 174.97	hafnium 72 <b>Hf</b> 178.49	tantalum 73 <b>Ta</b> 180.95	tungsten 74 <b>W</b> 183.84	rhenium 75 <b>Re</b> 186.21	osmium 76 <b>Os</b> 190.23	iridium 77 <b>Ir</b> 192.22	platinum 78 <b>Pt</b> 195.08	gold 79 <b>Au</b> 196.97	mercury 80 <b>Hg</b> 200.59	thallium 81 <b>Tl</b> 204.38	lead 82 <b>Pb</b> 207.2	bismuth 83 <b>Bi</b> 208.98	polonium 84 <b>Po</b> [209]	astatine 85 <b>At</b> [210]	radon 86 <b>Rn</b> [222]
francium 87 <b>Fr</b> [223]	radium 88 <b>Ra</b> [226]	89-102 * * Lr	lawrencium 103 <b>Lr</b> [262]	rutherfordium 104 <b>Rf</b> [261]	dubnium 105 <b>Db</b> [262]	seaborgium 106 <b>Sg</b> [263]	bohrium 107 <b>Bh</b> [264]	hassium 108 <b>Hs</b> [265]	meitnerium 109 <b>Mt</b> [268]	unnilium 110 <b>Uun</b> [271]	ununium 111 <b>Uuu</b> [272]	unbinium 112 <b>Uub</b> [277]	unquadrium 114 <b>Uuq</b> [289]					

\* Lanthanide series

57 <b>La</b>	58 <b>Ce</b>	59 <b>Pr</b>	60 <b>Nd</b>	61 <b>Pm</b>	62 <b>Sm</b>	63 <b>Eu</b>	64 <b>Gd</b>	65 <b>Tb</b>	66 <b>Dy</b>	67 <b>Ho</b>	68 <b>Er</b>	69 <b>Tm</b>	70 <b>Yb</b>
138.91	140.12	140.91	144.24	[145]	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04

\*\* Actinide series

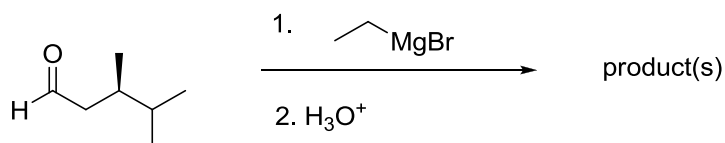
89 <b>Ac</b>	thorium 90 <b>Th</b>	protactinium 91 <b>Pa</b>	uranium 92 <b>U</b>	neptunium 93 <b>Np</b>	plutonium 94 <b>Pu</b>	americium 95 <b>Am</b>	curium 96 <b>Cm</b>	berkelium 97 <b>Bk</b>	californium 98 <b>Cf</b>	einsteinium 99 <b>Es</b>	fermium 100 <b>Fm</b>	mendeleevium 101 <b>Md</b>	nobelium 102 <b>No</b>
[227]	232.04	231.04	238.03	[237]	[244]	[243]	[247]	[247]	[251]	[252]	[257]	[258]	[259]

Circle the single best answer to each of the multiple choice questions 1-5.  
(25 pts)

1. Which of the following shows the correct order of reactivity toward Grignard reagents (least reactive to most reactive)?

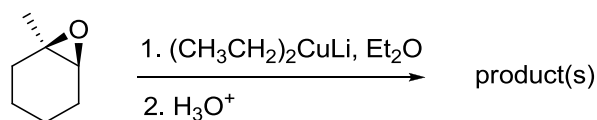
- a. Aldehyde < Ketone < Ester
- b. Ketone < Aldehyde < Ester
- c. Ester < Ketone < Aldehyde
- d. Ester < Aldehyde < Ketone
- e. Ketone < Ester < Aldehyde

2. When the following reaction 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

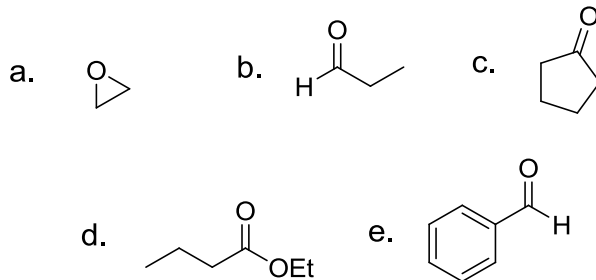
3. When the following reaction occurs, the product(s) will be:



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

Name \_\_\_\_\_ TA \_\_\_\_\_ Student # \_\_\_\_\_

4. Which of these compounds requires two equivalents of a Grignard or organolithium reagent for complete reaction?

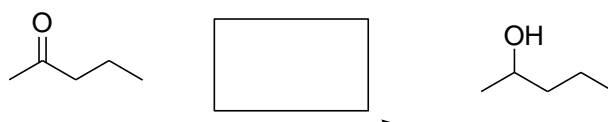
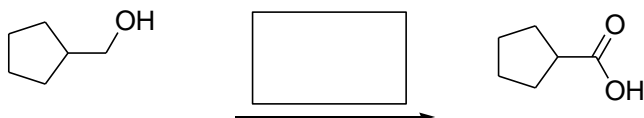
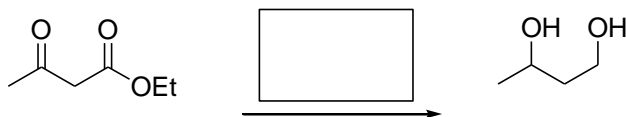
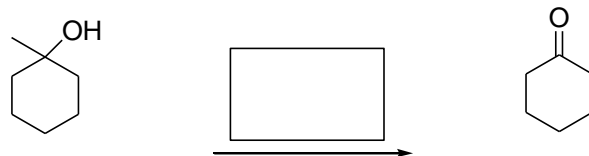
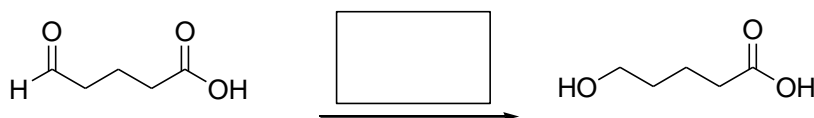
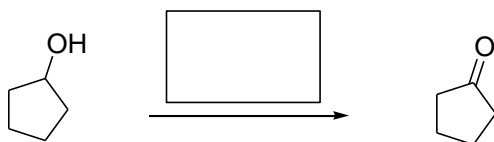


5. Using reactions you have seen in lecture, which of the following types of reagents cannot be used to synthesize a carboxylic acid from an appropriate organic starting material in one synthetic step (plus any necessary aqueous workup)?

- Grignard reagents
- Organocuprates
- Ozone, followed by hydrogen peroxide workup
- Jones reagent
- All of these reagents can be used to produce carboxylic acids from appropriate starting materials in one step

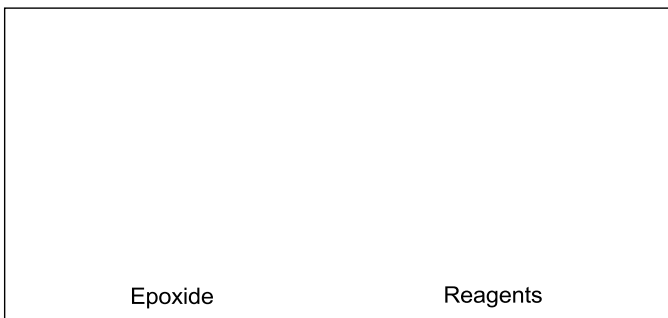
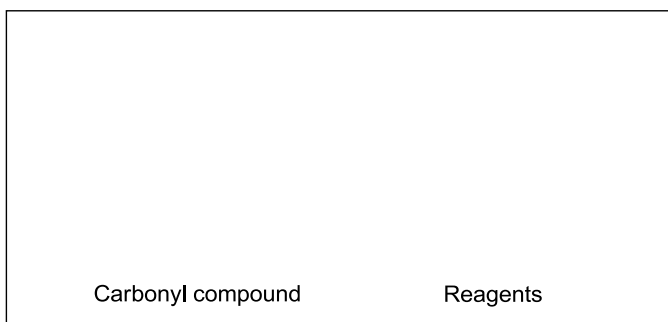
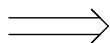
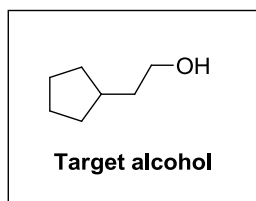
6. **Oxidation and reduction.** For each of the following transformations, choose the correct reagent or reagents from the list. Assume that you can use as much of each reagent as necessary (i.e. 1 equivalent, 2 equivalents, etc) and that every reaction has an appropriate aqueous workup. You can use a reagent more than once, or not at all. Put the letter that corresponds to your choice in the box above each arrow. (30 pts)

- A** Jones reagent ( $\text{H}_2\text{CrO}_4$ , acetone, water)  
**B** PCC or PDC  
**C**  $\text{NaBH}_4$   
**D** LAH, then  $\text{H}_3\text{O}^+$   
**E** A or B (either will work)  
**F** C or D (either will work)  
**G** Cannot be accomplished using any of these choices.



Name \_\_\_\_\_ TA \_\_\_\_\_ Student # \_\_\_\_\_

7. **Alcohol retrosynthesis.** This target alcohol can be made from various combinations of organic substrate and reagents. Provide the structures of an alkene, a carbonyl compound, and an epoxide from which this alcohol can be made in one synthetic step, along with the necessary reagents to convert each of these precursors to the alcohol. (15 pts)



8. **Multistep synthesis.** (30 pts) For each of the following transformations, propose a synthesis of the target molecule from the starting material shown.

For full credit:

- Show reagents needed for each step and the product of each step. This means don't just write a list of reagents over the arrow and you will lose many points if you do it that way. The format should be  $A \rightarrow B \rightarrow C$ , with the reagents written over the arrow for each transformation.
- If you use an organometallic reagent, you do not need to show how you made it.

