

Please sign the Honor Pledge.

I pledge that

“On my honor, as a University of Colorado-Boulder student, I have neither given nor received unauthorized assistance on this work.”

\_\_\_\_\_  
PRINT Last Name, First Name, Middle Initial

\_\_\_\_\_  
Please Sign Here

**Recitation TA's name:** \_\_\_\_\_

**Recitation Day and Time:** \_\_\_\_\_

*PLEASE legibly print your name on each page of the exam.*

**Partial Periodic Table**

1A							8A
1 H							2 He
	2A						
3 Li	4 Be						
		3A	4A	5A	6A	7A	10 Ne
		5 B	6 C	7 N	8 O	9 F	
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
						35 Br	
						53 I	

Recit.	Location	Day	Time	TA
215	EKLC M2B36	Mon	1:00-1:50 PM	Matthew Farmer
227	EKLC M2B36	Tue	3:00-3:50 PM	Ethan Miller
234	EKLC M2B36	Wed	12:00-12:50 PM	Matthew Farmer
236	EKLC M2B36	Wed	2:00-2:50 PM	Ethan Miller
238	EKLC M2B36	Wed	4:00-4:50 PM	Thomas Carey
243	EKLC M2B36	Thu	11:00-11:50 AM	Aaron Crossman
245	EKLC M2B36	Thu	1:00-1:50 PM	Aaron Crossman

*PLEASE read the questions very carefully!*

This is a closed-book exam.

The use of notes, calculators, scratch paper, or cell phones will **not** be allowed during the exam.

You may use models brought in a clear ziploc bag.


Please put all your answers on the test in the appropriate place. Use the backs of the pages for scratch (there are two additional blank scratch sheets after the last page of the exam). **DO NOT PUT ANSWERS ON THE SCRATCH SHEETS.**

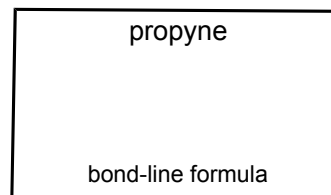
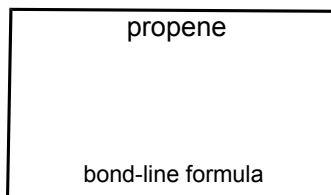
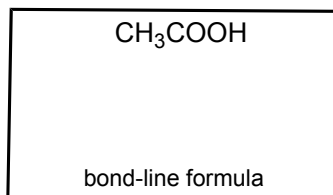
**Table of Acidities**

<u>Acid</u>	<u>pK<sub>a</sub> Value</u>	<u>Acid</u>	<u>pK<sub>a</sub> Value</u>	<u>Grading (Points Earned)</u>
HI	-10	Thiol (RSH)	10-12	
HBr	-8.5	H <sub>2</sub> O	15.7	Question 1 (17) _____
HCl	-6	Alcohol (ROH)	16-18	Question 2 (12) _____
H <sub>3</sub> O <sup>+</sup>	-1.7	HC≡CH	26	Question 3 (5) _____
HF	3.2	NH <sub>3</sub>	36	Question 4 (10) _____
CH <sub>3</sub> COOH	4.7	H <sub>2</sub>	37	Question 5 (22) _____
HN <sub>3</sub> (hydrazoic acid)	4.7	H <sub>2</sub> C=CH <sub>2</sub>	45	Question 6 (17) _____
NH <sub>4</sub> <sup>+</sup>	9.3	CH <sub>4</sub>	60	Question 7 (17) _____
Phenol	10			TOTAL _____

Name: \_\_\_\_\_

**1 A.** Draw ***bond-line formulas*** for the molecules shown below and ***circle all the molecules containing one or more  $sp^2$ -hybridized carbon atoms***. Show ***all lone pairs and formal charges*** if applicable. (7 points)

Example: Bond-line formula for butane is 



**1 B.** Using the skeletal framework below, draw all the ***hybrid orbitals*** participating in ***sigma bonding*** in allene, H<sub>2</sub>C=C=CH<sub>2</sub>. Label each hybrid orbital as *sp*, *sp*<sup>2</sup>, or *sp*<sup>3</sup>. Include the orbitals involved in the C-H sigma bonds. (6 points)

C

C

C

Using the skeletal framework below, draw the orbitals participating in ***pi bonding*** in allene, H<sub>2</sub>C=C=CH<sub>2</sub>, and show the interactions resulting in pi bonds. (4 points)

C

C

C

**2.** The azide ion, N<sub>3</sub><sup>-</sup>, is a good nucleophile in substitution reactions of alkyl halides such as CH<sub>3</sub>I.

How many valence electrons are there in the azide ion? \_\_\_\_\_ (2 points)

Draw ***three*** Lewis structures (all atoms have octets) for the resonance-stabilized azide ion. You must show ***all lone pairs and formal charges***. Circle the major contributing structure. (10 points)

(NOTE: On scratch paper, you may use the curved arrow notation to guide you in this process.)

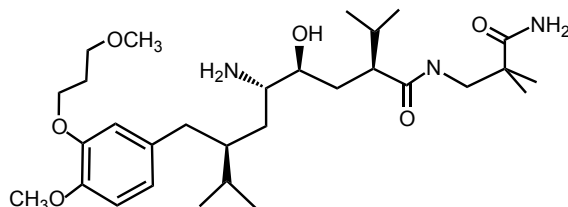


Points earned: **Question 1** \_\_\_\_\_

**Question 2** \_\_\_\_\_

Name: \_\_\_\_\_

3. Aliskiren (Tekturna) is an antihypertensive agent that blocks the enzyme renin, an important regulator of blood pressure. Which of the listed functional groups does Aliskiren contain? Circle ALL that apply. Points will be deducted for incorrect answers. (5 points)



alcohol	alkene	aldehyde	amide	amine
aromatic ring	ester	ether	ketone	phenol

4. Draw, **using only bond-line formulas**, all constitutionally isomeric **cycloalkanes and substituted cycloalkanes** with the molecular formula  $C_5H_{10}$ . Write the correct IUPAC name for each. NOTE: Be careful to draw each isomer only once; points will be taken off for missing and redundant (unnecessary repetition) structures. (10 points)

Bond-line formula	IUPAC Name

Points earned: **Question 3** \_\_\_\_\_

**Question 4** \_\_\_\_\_

Name: \_\_\_\_\_

**5 A.** For each pair of molecules or charged species, circle the stronger Brønsted acid, and indicate with a check mark the **best** reason for your choice. (6 points)

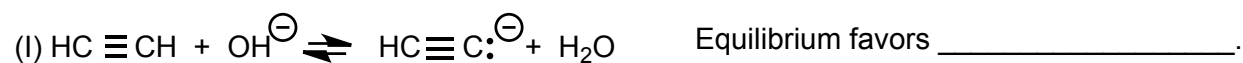
	Charge Effect	Element Effect	Hybridization Effect	Resonance Effect	Inductive Effect
CH <sub>3</sub> CH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub> C≡CH					
CH <sub>3</sub> CH <sub>2</sub> OH    CH <sub>3</sub> CH <sub>2</sub> SH					
CH <sub>3</sub> COOH    CCl <sub>3</sub> COOH					

**5 B.** Consider these bases: CH<sub>3</sub>CH<sub>2</sub>NH<sub>2</sub>, CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub><sup>-</sup>, and CH<sub>3</sub>CH<sub>2</sub>O<sup>-</sup>. (4 points)

Select the most basic species: \_\_\_\_\_

Select the least basic species: \_\_\_\_\_

**5 C.** For each reaction, indicate whether equilibrium favors reactants or products. (4 points)



**5 D.** Use the curved arrow notation to represent proton transfer in the reaction shown below: Draw lone pairs on the S and O atoms in the reactants and products. (8 points)



Points earned: **Question 5** \_\_\_\_\_

Name: \_\_\_\_\_

**6 A.** Consider these compounds:  $\text{CH}_3\text{F}$ ,  $\text{CH}_3\text{OH}$ , and  $\text{CH}_3\text{NH}_2$ .

Select the compound with the **lowest** boiling point: \_\_\_\_\_ (2 points)

Select the compound with the **highest** boiling point: \_\_\_\_\_ (2 points)

**6 B.** Consider these compounds: 2-methylbutane, 2,2-dimethylpropane, and pentane.

Draw **bond-line formulas** for each compound. (3 points)

2-methylbutane



2,2-dimethylpropane



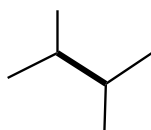
pentane



Select the compound with the **lowest** boiling point: \_\_\_\_\_ (2 points)

Select the compound with the **highest** boiling point: \_\_\_\_\_ (2 points)

**6 C.** Draw Newman projections for the (I) most stable and (II) least stable conformations of 2,3-dimethylbutane (structure shown below), **sighting along the C2-C3 bond**. The information provided may be useful; you are not required to complete any detailed energy calculations. (6 points)



Interaction	Energy Cost (kcal/mol)
H/H eclipsed	0.97
H/ $\text{CH}_3$ eclipsed	1.3
$\text{CH}_3/\text{CH}_3$ eclipsed	3.4
$\text{CH}_3/\text{CH}_3$ gauche	0.9

Most Stable Conformation	Least Stable Conformation

Points earned: **Question 6** \_\_\_\_\_

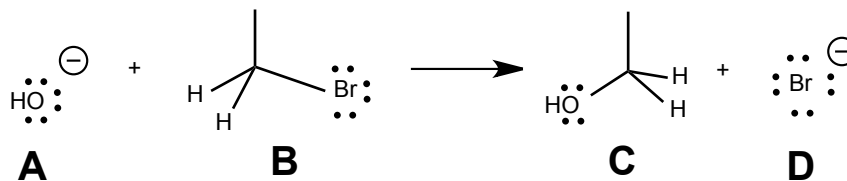
Name: \_\_\_\_\_

**7 A.** Draw the MO diagram for  $\text{He}_2^+$ . Clearly label atomic and molecular orbitals, and indicate electron occupancy in each of these. (8 points)

What is the bond order for  $\text{He}_2^+$ ? \_\_\_\_\_ (1 point)

**7 B.** Draw the curved arrows to illustrate the mechanism for product formation in each reaction. Identify the HOMO and LUMO in each reaction. Identify the electrophile and nucleophile in (I) and the Brønsted acid and base in (II). (8 points)

(I)



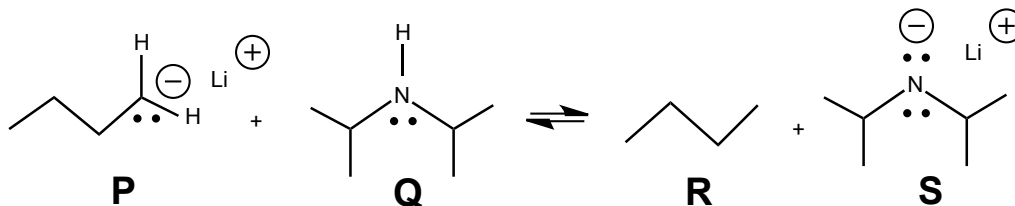
HOMO: \_\_\_\_\_

LUMO: \_\_\_\_\_

Electrophile: \_\_\_\_\_

Nucleophile: \_\_\_\_\_

(II)



HOMO: \_\_\_\_\_

LUMO: \_\_\_\_\_

Brønsted acid: \_\_\_\_\_

Brønsted base: \_\_\_\_\_

Points earned: **Question 7** \_\_\_\_\_