

CHEM 3311  
Dr. Minger

Hour Exam #2  
June 19, 2018

Name \_\_\_\_\_

Circle your recitation section: 111 112 113 114 115  
121 122 123 124 125 141 142

Sign the Honor Code pledge:

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, including one extra credit question. 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. **DO NOT USE COLORED INK.** Your scratch work will not be graded, so be sure everything you want graded is written on the exam itself. There is only one correct answer to each multiple choice question; only your final answer will be considered and no partial credit will be awarded for scratch work on multiple choice questions.



Good luck!

1A	2A	3A	4A	5A	6A	7A	8A
Hydrogen 1 <b>H</b> 1.00794	Lithium 3 <b>Li</b> 6.941	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	Helium 2 <b>He</b> 4.0026
Beryllium 4 <b>Be</b> 9.0122	Sodium 11 <b>Na</b> 22.990	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	Neon 10 <b>Ne</b> 20.180
Potassium 19 <b>K</b> 39.098	Calcium 20 <b>Ca</b> 40.078	Gallium 31 <b>Ga</b> 69.723	Germanium 32 <b>Ge</b> 72.64	Arsenic 33 <b>As</b> 74.922	Selenium 34 <b>Se</b> 78.96	Bromine 35 <b>Br</b> 79.904	Argon 18 <b>Ar</b> 39.948
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]	Krypton 36 <b>Kr</b> 83.80
Cesium 55 <b>Cs</b> 132.91	Barium 56 <b>Ba</b> 137.33	Lanthanum 57 <b>La</b> 138.91	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	Xenon 54 <b>Xe</b> 131.29
Radium 87 <b>Fr</b> [223]	Ra 88 <b>Ra</b> [226]	* 57-70 <b>Lu</b> [175]	* 89-102 <b>Lr</b> [260]	<b>Hf</b> 103 <b>Hf</b> 178.49	<b>Ta</b> 104 <b>Ta</b> 180.95	<b>W</b> 105 <b>W</b> 183.84	<b>Os</b> 76 <b>Os</b> 190.23
				<b>Ir</b> 106 <b>Ir</b> 192.22	<b>Pt</b> 107 <b>Pt</b> 195.08	<b>Au</b> 108 <b>Au</b> 196.97	<b>Rn</b> 86 <b>Rn</b> [222]
				<b>Rh</b> 45 <b>Rh</b> 101.07	<b>Pd</b> 46 <b>Pd</b> 106.42	<b>Ag</b> 47 <b>Ag</b> 107.87	<b>Uuo</b> 112 <b>Uuo</b> [289]
				<b>Cd</b> 48 <b>Cd</b> 112.41	<b>In</b> 49 <b>In</b> 114.82	<b>Sn</b> 50 <b>Sn</b> 118.71	<b>Uuq</b> 114 <b>Uuq</b> [289]
				<b>Cu</b> 29 <b>Cu</b> 63.546	<b>Zn</b> 30 <b>Zn</b> 65.38	<b>Ga</b> 31 <b>Ga</b> 69.723	
				<b>Ni</b> 28 <b>Ni</b> 58.693	<b>Cu</b> 29 <b>Cu</b> 63.546	<b>Zn</b> 30 <b>Zn</b> 65.38	
				<b>Co</b> 27 <b>Co</b> 58.933	<b>Ni</b> 28 <b>Ni</b> 58.693	<b>Cu</b> 29 <b>Cu</b> 63.546	
				<b>Fe</b> 26 <b>Fe</b> 55.845	<b>Co</b> 27 <b>Co</b> 58.933	<b>Ni</b> 28 <b>Ni</b> 58.693	
				<b>Mn</b> 25 <b>Mn</b> 54.938	<b>Fe</b> 26 <b>Fe</b> 55.845	<b>Co</b> 27 <b>Co</b> 58.933	
				<b>Cr</b> 24 <b>Cr</b> 51.996	<b>Mn</b> 25 <b>Mn</b> 54.938	<b>Fe</b> 26 <b>Fe</b> 55.845	
				<b>V</b> 23 <b>V</b> 50.942	<b>Cr</b> 24 <b>Cr</b> 51.996	<b>Mn</b> 25 <b>Mn</b> 54.938	
				<b>Ti</b> 22 <b>Ti</b> 47.867	<b>V</b> 23 <b>V</b> 50.942	<b>Cr</b> 24 <b>Cr</b> 51.996	
				<b>Sc</b> 21 <b>Sc</b> 44.956	<b>Ti</b> 22 <b>Ti</b> 47.867	<b>V</b> 23 <b>V</b> 50.942	

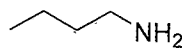
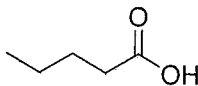
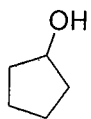
\* Lanthanide series

\*\* Actinide series

Lanthanum 57 <b>La</b> 138.91	Cerium 58 <b>Ce</b> 140.12	Praseodymium 59 <b>Pr</b> 140.91	Ndium 60 <b>Nd</b> 144.24	Promethium 61 <b>Pm</b> [145]	Samarium 62 <b>Sm</b> 150.36	Europium 63 <b>Eu</b> 151.96	Gadolinium 64 <b>Gd</b> 157.25	Terbium 65 <b>Tb</b> 158.93	Dysprosium 66 <b>Dy</b> 162.50	Holmium 67 <b>Ho</b> 164.93	Erbium 68 <b>Er</b> 167.26	Thulium 69 <b>Tm</b> 168.93	Ytterbium 70 <b>Yb</b> 173.04
Actinium 89 <b>Ac</b> [227]	Thorium 90 <b>Th</b> 232.04	Protactinium 91 <b>Pa</b> 231.04	Uranium 92 <b>U</b> 238.03	Neptunium 93 <b>Np</b> [237]	Plutonium 94 <b>Pu</b> [244]	Americium 95 <b>Am</b> [243]	Curium 96 <b>Cm</b> [247]	Berkelium 97 <b>Bk</b> [247]	Californium 98 <b>Cf</b> [251]	Einsteinium 99 <b>E</b> [252]	Fermium 100 <b>Fm</b> [257]	Mendelevium 101 <b>Md</b> [258]	Noelium 102 <b>No</b> [259]



1a) Arrange the three acids in order of **decreasing**  $pK_a$ . (Highest to lowest) (5 pts)



**W**

**X**

**Y**

- a.  $W > X > Y$
- b.  $Y > X > W$
- c.  $Y > W > X$
- d.  $W > Y > X$
- e.  $X > Y > W$

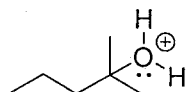
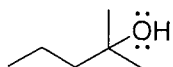
1b) Using a conjugate base stability argument, which of these factors is the best explanation for the difference in acidity between structures **W** and **X** in question 1a? (5 pts)

- a. Resonance
- b. Electronegativity
- c. Charge
- d. Size/Polarizability

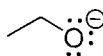
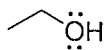
1c) Using a conjugate base stability argument, which of these factors is the best explanation for the difference in acidity between structures **W** and **Y** in question 1a? (5 pts)

- a. Resonance
- b. Electronegativity
- c. Inductive effect
- d. Size/Polarizability

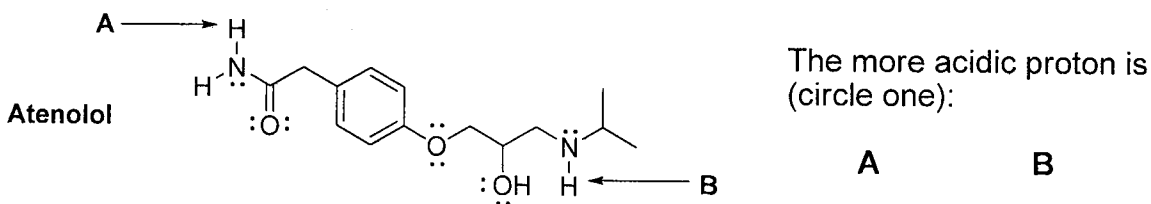
1d) Circle the stronger acid (5 pts):



1e) Circle the stronger base (5 pts):

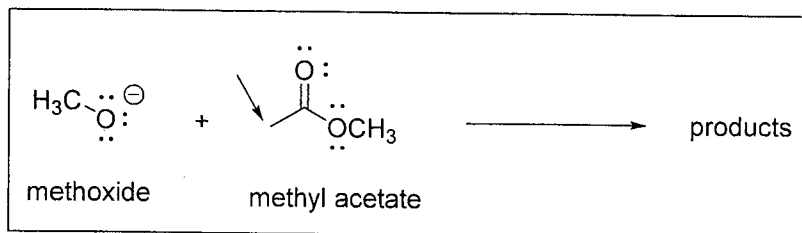


- 2) Atenolol is a beta blocker used to treat high blood pressure. Which proton is more acidic, A or B? Explain your reasoning, using a conjugate base stability argument. To receive credit, you must explain WHY one conjugate base is more stable than the other. (10 pts)



Reason (one or two sentences):

- 3) When methoxide ion, a Bronsted base, is combined with methyl acetate, a Bronsted acid ( $pK_a = 24$ ), as shown in this partial equation, a proton transfer occurs. The most acidic protons in methyl acetate are attached to the carbon designated with the arrow. You will need to draw one of these hydrogens explicitly in your mechanism.



- 3a) (10 pts) Using curved arrows, draw a mechanism for this proton transfer reaction. (Redraw the structures below. Do not draw your mechanism on the structures shown above.) Draw the products of this reaction. Show all lone pairs and non-zero formal charges.

- 3b) (3 pts) Estimate the equilibrium constant for the reaction:  $K = \underline{\hspace{2cm}}$

- 3c) (2 pts) State which side of the reaction is favored at equilibrium by circling the correct response:                      **Reactants (left)**                      **Products (right)**

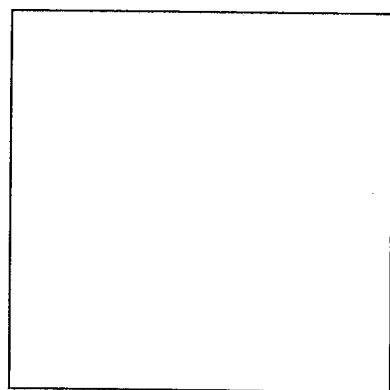
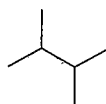
4a) Circle the ring with the MOST strain (4 pts):



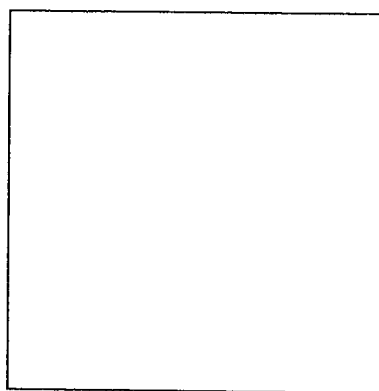
4b) Circle the ring with the LEAST strain (4 pts):



4c) Draw the requested Newman projections of 2,3-dimethylbutane looking down the C2-C3 bond. Then identify the type(s) of strain present in each conformation by circling the correct response. *Hint:* Be sure you are drawing the correct molecule, or you will not get full credit. (10 pts)



Most stable



Least stable

4d) (7 pts) Identify all type(s) of strain present in the MOST stable conformation you just drew. Possibilities include torsional, angle, steric, and "none".

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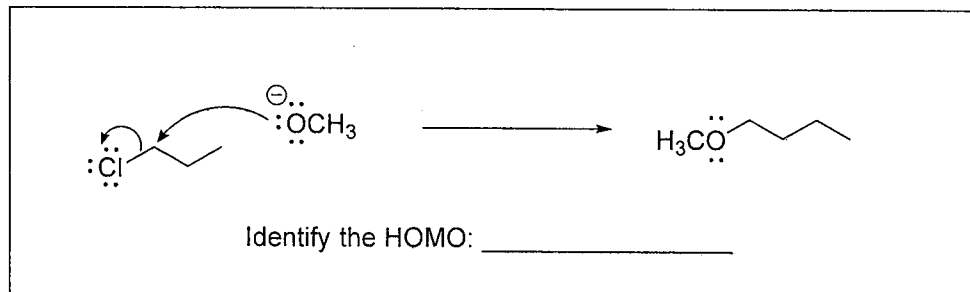
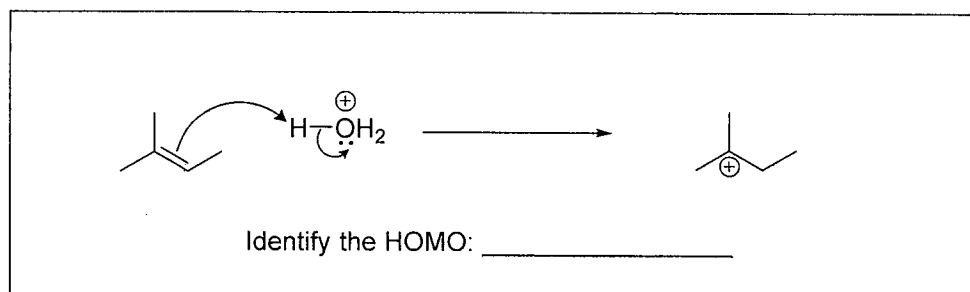
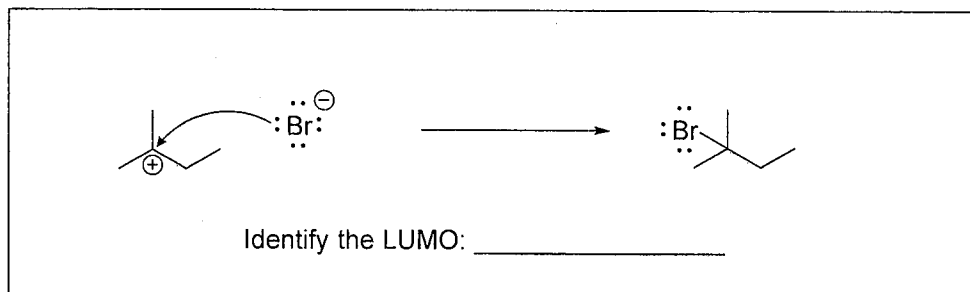
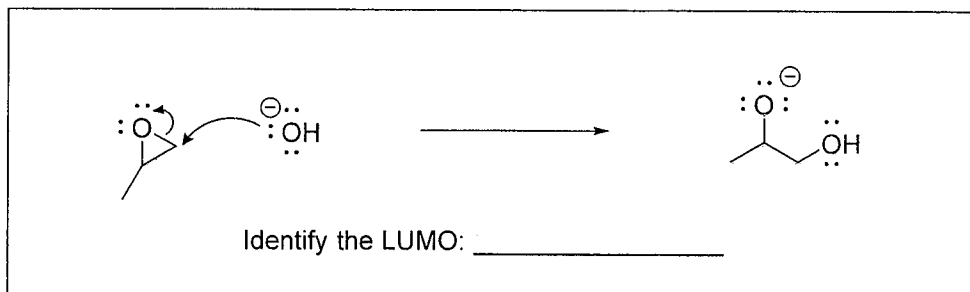
Identify all type(s) of strain present in the LEAST stable conformation you just drew. Possibilities include torsional, angle, steric, and "none".

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How many gauche butane interactions are there in the MOST stable conformation? Write the number here: \_\_\_\_\_

How many gauche butane interactions are there in the LEAST stable conformation? Write the number here: \_\_\_\_\_

5a) Identify the requested orbital for each of the following mechanisms (e.g. what kind of orbital is the HOMO or LUMO in each case) (16 pts).



5b) True or False? Write the correct response on the line before each statement (9 pts)

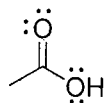
\_\_\_\_\_ A bonding molecular orbital is the result of an out-of-phase combination of atomic orbitals.

\_\_\_\_\_ The bond order of H<sub>2</sub> is 2.

\_\_\_\_\_ A C-C π\* orbital (e.g. in ethylene) has one nodal plane (one node).

6) Extra credit. (10 pts)

In the presence of a strong acid like HCl, a carboxylic acid will be protonated. Which of the two oxygen atoms is most likely to get protonated (i.e., which oxygen atom is more basic), and why? Support your answer using appropriate chemical structures that include all lone pairs and nonzero formal charges.



The more basic oxygen atom is (circle one):

**The carbonyl oxygen**

**The OH group oxygen**

Now show why using structures and explanations:

