

CHEM 3311-200
Exam 1 ANSWER KEY
February 10, 2015

Assigned Seat # _____

Time: 2 Hours

Please sign the Honor Pledge.

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

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General Instructions: (I) Scantron: Questions 1-20 (75 pts) AND (II) Short Answers: Questions 21-23 (25 pts)

Section I: Complete the information requested on the scantron and bubble in the appropriate spaces using a No. 2 pencil.

If you change an answer, erase the undesired mark thoroughly. Mark only the best answer to each multiple-choice question. Use the back of the exam pages (for multiple choice questions 1-20 only) as scratch paper. There are 5 exam pages (with 20 MC questions and 3 short answer questions), a cover page, and two blank pages (scratch paper). When you are instructed to begin the exam, please check that you have all pages. Good luck!

Please return the completed scantron sheet, SHORT ANSWER section, and this cover page (signed Honor Code) to the exam proctors. You may take the MULTIPLE-CHOICE section of the exam and scratch paper with you.

Partial Periodic Table

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

Recit.	Location	Day	Time	TA
221	EKLC M2B26	Tue	9:00 AM - 9:50 AM	Ed Guzman
222	EKLC M2B26	Tue	10:00 AM - 10:50 AM	Ed Guzman
226	EKLC M2B26	Tue	12:00 PM - 12:50 PM	Will Hartwig
230	EKLC M2B26	Wed	8:00 AM - 8:50 AM	Jordan Theriot
238	EKLC M2B26	Wed	4:00 PM - 4:50 PM	Jordan Theriot
244	EKLC M2B26	Thu	11:00 AM - 11:50 AM	Will Hartwig
247	EKLC M2B26	Thu	1:00 PM - 1:50 PM	Price Kirby

Useful Information

$$\Delta G^\circ = -RT \ln K_a$$

$$K_{eq} = 10^{[(pK_a, BH^+) - (pK_a, HA)]}$$

$$\ln x = 2.303 \log x$$

Table of Acidities

Acid	pK _a Value	Acid	pK _a Value
HI	-10.1	H ₂ O	15.7
HCl	-3.9	Alcohols	16-18
H ₃ O ⁺	-1.7	HC≡CH	26
CH ₃ COOH	4.7	NH ₃	36
NH ₄ ⁺	9.3	H ₂ C=CH ₂	45
Phenol	10	CH ₄	60

Section IA: Questions 1-5 (3 points each; total: 15 points)

1) What is the molecular formula for butane?

- (A) C₃H₆ (B) C₃H₈ (C) C₄H₈ **(D) C₄H₁₀**

2) What is the functional group in CH₃COCH₃? Hint: Draw a Lewis structure.

- (A) aldehyde (B) ester **(C) ketone** (D) ether

3) Select the molecule that is an amide.

- (A) CH₃CHO (B) CH₃COOCH₂CH₃
(C) CH₃CONHCH₃ (D) CH₃NH₂

4) Which is the strongest acid?

- (A) NH₄⁺** (B) HC≡CH (C) NH₃ (D) C₂H₆

5) Which is the strongest base?

- (A) OH⁻ **(B) CH₃CH₂CH₂CH₂⁻** (C) NH₂⁻ (D) CH₃O⁻

Section IB: Questions 6-20 (4 points each; total: 60 points)

6) Which molecule is linear?

- (A) C₃H₈ (B) C₂H₆ (C) C₂H₄ **(D) C₂H₂**

7) What is the hybridization of the *central* carbon atom in allene, H₂C=C=CH₂?

- (A) sp** (B) sp² (C) sp³ (D) none of these

8) Studies indicate that the methyl radical, H₃C·, has a trigonal planar shape. Using this information, select the statement that best describes bonding in the methyl radical?

- (A) The carbon is sp³ hybridized and the unpaired electron occupies a 2p orbital.
(B) The carbon is sp³ hybridized and the unpaired electron occupies an sp³ orbital.
(C) The carbon is sp² hybridized and the unpaired electron occupies a 2p orbital.
(D) The carbon is sp² hybridized and the unpaired electron occupies an sp² orbital.

9) Draw the best Lewis structure for the nitronium ion, NO₂⁺. What is the formal charge on the *central N atom* in this structure?

- (A) 0 **(B) +1** (C) -1 (D) +2

10) Which organic solvent is nonpolar?

- (A) **Hexane** (B) Dichloromethane (C) CH₃OCH₃ (D) CH₃OH

11) Which compound releases the most heat in kJ/mol on combustion?

- (A) 2-Methylpropane (B) 2-Methylbutane (C) 2-Methylpentane (D) **2-Methylhexane**

12) Why can heats of combustion data for *isomeric hydrocarbons* be used to compare their relative stabilities?

- (I) Combustion of isomers gives different final energy states.
 (II) **Combustion of isomers gives the same final energy states.**
 (III) **Isomeric hydrocarbons have different potential energies.**
 (IV) Isomeric hydrocarbons have the same potential energies.

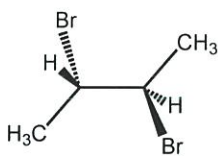
- (A) I and III (B) **II and III** (C) I and IV (D) II and IV

13) Arrange these alkanes in order of *decreasing boiling point*.

- (I) *n*-Heptane
 (II) 2,2,3-Trimethylbutane
 (III) 2,3-Dimethylpentane

- (A) I > II > III (B) II > III > I (C) III > I > II (D) **I > III > II**

14) What is the dihedral angle between the two bromine atoms in the wedge-and dash projection shown?



- (A) 60° (B) 90° (C) 120° (D) **180°**

15) Draw the potential energy (PE) diagram for rotation about the C2-C3 bond in 2,2-dimethylpropane. Select all the statements that *correctly* describe this potential energy diagram.

- (I) **All the eclipsed conformations are equivalent and represent potential energy maxima.**
 (II) **All the staggered conformations are equivalent and represent potential energy minima.**
 (III) The shape of the PE profile more closely resembles that of butane.

- (A) **I and II** (B) I and III (C) II and III (D) I, II, and III

16) Which classification best describes the $B(CH_3)_3$ molecule?

- (A) Brønsted acid (B) Brønsted base **(C) Lewis acid** (D) Lewis base

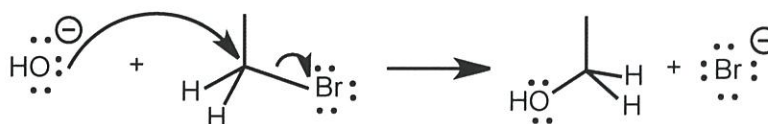
17) What is the magnitude of the equilibrium constant when trimethylamine, $(CH_3)_3N$, reacts with HCl.

- (A) $K = 0$ (B) $K = 1$ **(C) $K \gg 1$** (D) $K \ll 1$

18) Using MO theory, select the species that does not exist?

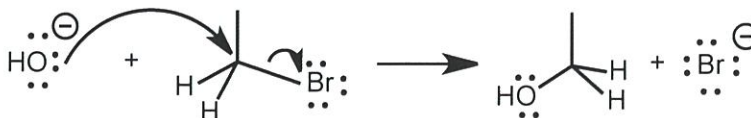
- (A) H_2 (B) H_2^+ (C) H_2^- **(D) H_2^{2-}**

19) Frontier orbitals participate in an organic chemical reaction. Examine the nucleophilic substitution reaction shown below and identify the HOMO and LUMO in this example.



- (A) HOMO is σ^*_{O-H} in the hydroxide ion; LUMO is σ^*_{C-Br}
 (B) HOMO is σ^*_{O-H} in the hydroxide ion; LUMO is σ_{C-Br}
(C) HOMO is the nonbonding MO in the hydroxide ion; LUMO is σ^*_{C-Br}
 (D) HOMO is the nonbonding MO in the hydroxide ion; LUMO is σ_{C-Br}

20) Which is the nucleophile in the reaction shown?



- (A) Hydroxide ion** (B) CH_3CH_2Br (C) CH_3CH_2OH (D) Bromide ion

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Recitation Section # _____
(Note: -5 points for missing
Recitation section #)

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Section II: SHORT ANSWER Questions 21-23 (total: 25 points)

For Grading Purposes Only

Points Earned on Short Answer Section

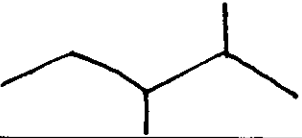

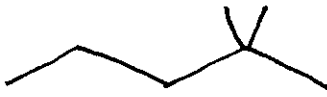

Question 21 (10 points) _____

Question 22 (5 points) _____

Question 23 (10 points) _____

Total Points (25 possible) _____

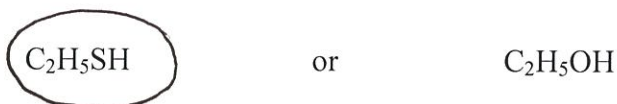
21) Consider the constitutional isomers of C_7H_{16} . Draw, using BOND LINE formulas, only those isomers that are *substituted pentanes*. Any FOUR substituted pentanes of C_7H_{16} are acceptable (4 points). Write the correct IUPAC name for each isomer (6 points).

	Bond-line Formulas of Isomeric Pentanes	IUPAC Names of Isomeric Pentanes
(1)		2,3-dimethylpentane
(2)		2,4-dimethylpentane
(3)		2,2-dimethylpentane
(4)		3,3-dimethylpentane

Points earned on this page ____/10

22) Ethane thiol, C_2H_5SH , has a $pK_a = 10.5$ compared to a value of 15.9 for ethanol, C_2H_5OH .

(A) **Circle** the stronger acid. (2 points)



(B) **Briefly** explain (only 1 or 2 sentences) your reasoning in terms of the relationship between structure and acid strength. (3 points)

• Element effect, going down group, longer S-H bond, weaker bond, relatively stronger acid

or

• Greater relative stability of S^- due to greater polarizability; acid dissociation equilibrium

23) 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. Note: In general, stronger bonds are shorter bonds. (10 points)

		Charge Effect	Resonance Effect	Relative Electronegativities	Relative Bond Strengths
CH_3OH	$(CH_3)_2NH$			✓	
CH_3OH	$CH_3OH_2^+$	✓			
HF	HBr				✓
CH_3COOH	C_2H_5OH		✓		
NH_3	CH_4			✓	

favors product more for SH than OH