

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 25 questions. Be sure you have them all. Read each question carefully so that you know exactly what is being asked.

Each multiple choice question (1-25) is worth **4 points** and has **only one correct answer**. Bubble in your answers to these questions on the Scantron provided. **Only the Scantron will be graded, not anything that you write on the exam.**

At the end of the exam, turn in your Scantron and this signed cover sheet. You may keep the rest of the exam to check your answers against the key later.

Good luck!

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

hydrogen 1 H 1.0079																								helium 2 He 4.0026												
lithium 3 Li 6.941	beryllium 4 Be 9.0122																								boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180						
sodium 11 Na 22.990	magnesium 12 Mg 24.305																								aluminum 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948						
potassium 19 K 39.098	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80																			
rubidium 37 Rb 85.468	strontium 38 Sr 87.62	yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	nickel 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29																			
cesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]																		
francium 87 Fr [223]	radium 88 Ra [226]	89-102 **	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [269]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	unnilium 110 Uu [271]	ununium 111 Uu [272]	unbinium 112 Uu [272]																								

* Lanthanide series

lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
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** Actinide series

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

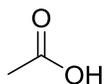
pK_a values: H₃O⁺, -1.7

NH₄⁺, 9

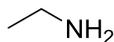
CH₃CH₂OH, 16

CH₃OH₂⁺, -2

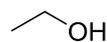
1. Arrange the three acids in order of **increasing** acidity.



X

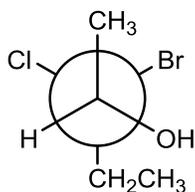


Y



Z

- a. X > Y > Z
b. Z > Y > X
c. X > Z > Y
d. Y > Z > X
e. Y > X > Z
2. In this Newman projection, which of the following pairs of groups does **not** represent an anti relationship?



- a. CH₃ and Br
b. H and Br
c. Cl and OH
d. CH₃ and CH₂CH₃
e. All of the listed pairs are in an anti relationship
3. What type of strain is present in the **highest energy** conformer of butane?
- a. Torsional
b. van der Waals
c. Angle
d. Torsional and van der Waals
e. There is no strain in that conformer

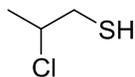
4. A proton transfer (Bronsted acid-base reaction) occurs between the two compounds shown. (The spectator ion is omitted for clarity.) Select the number that is the **best** estimate of the equilibrium constant for this reaction.



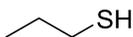
- a. 10^4
 b. 10^{-4}
 c. 10^{11}
 d. 10^{-11}
 e. 10^{20}
5. The **base** in the reaction in #4 is a/an:

- a. hydroxide
 b. carboxylate
 c. alkoxide
 d. alcohol
 e. none of these

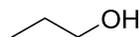
6. Arrange the three acids in order of **decreasing** pK_a .



P



Q



R

- a. $P > Q > R$
 b. $R > Q > P$
 c. $R > P > Q$
 d. $P > R > Q$
 e. $Q > R > P$
7. Select the weakest acid.



A



B

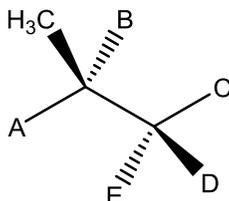


C



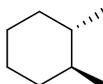
D

8. In the structure shown, which of the indicated groups is **anti** to the methyl group?

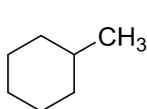


9. Select the weakest acid.

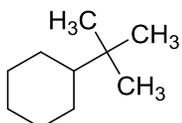
- H_2O
 - CH_4
 - NH_3
 - HBr
 - CH_3OH
10. What is the approximate difference in energy between the two chair conformations of this molecule?



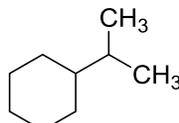
11. Which of the following monosubstituted cyclohexanes would exhibit the **least** preference for having the substituent in an *equatorial* position?



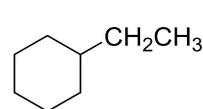
A



B

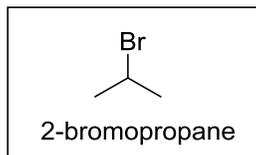


C



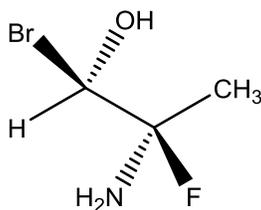
D

12. Use the table of energies provided to calculate the strain energy of the **highest energy conformation** of 2-bromopropane looking down C1-C2.



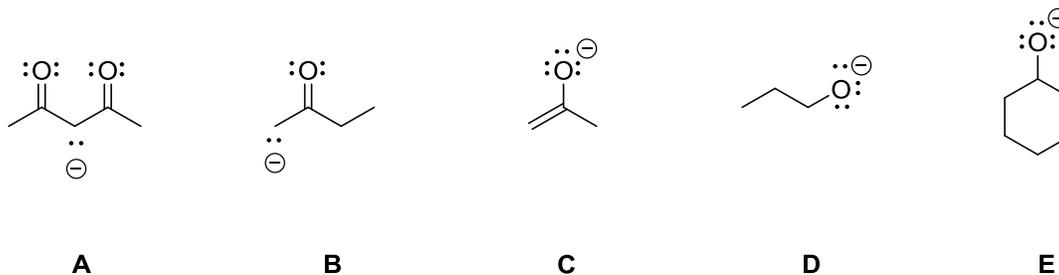
Interaction	Energy (kcal/mol)
H-H eclipse	1.0
CH ₃ -H eclipse	1.3
Br-H eclipse	1.5
Br-CH ₃ gauche	1.0
Br-CH ₃ eclipse	3.0
Br-CH ₃ anti	0

- a. 3.5 kcal/mol
b. 3.8 kcal/mol
c. 4.0 kcal/mol
d. 5.5 kcal/mol
e. None of these values
13. Which of these numbers is closest to the value of the torsion angle between OH and CH₃ in this conformer?

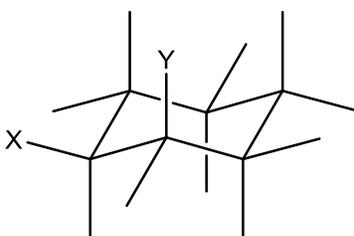


- a. 30°
b. 45°
c. 60°
d. 109.5°
e. 180°

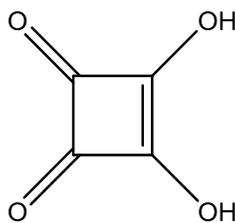
14. Select the weakest base.



15. In this chair structure, substituents “X” and “Y” are:



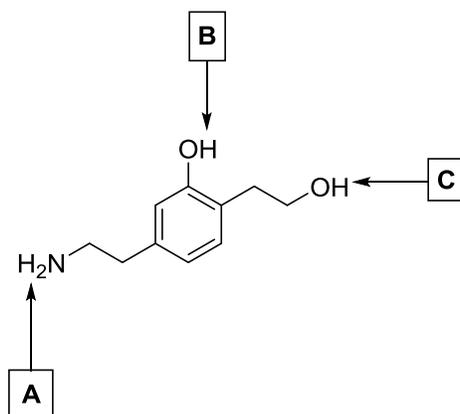
- a. anti and trans
 - b. anti and cis
 - c. gauche and trans
 - d. gauche and cis
 - e. none of these
16. Squaric acid has a pK_a of 1.5. When it is placed in water, an acid-base reaction occurs. What is the LUMO in the reaction?



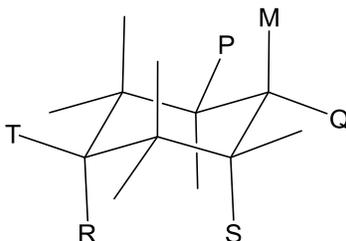
squaric acid

- a. O-H σ
- b. O-H σ^*
- c. C-O π
- d. Nonbonding MO in water
- e. None of these

17. A molecule may have more than one acidic hydrogen atom. Using your knowledge of the factors influencing acidity, which of the indicated hydrogen atoms in this molecule is **most** acidic? (Notice that "A" refers to either of the protons attached to N.)



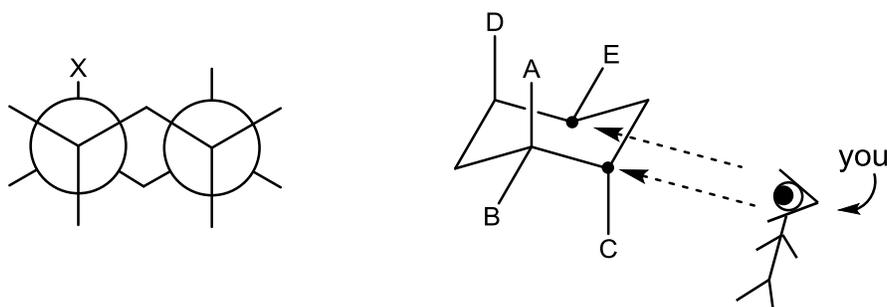
- A
 - B
 - C
 - All the indicated protons are equally acidic
 - B and C are equally acidic, and A is less acidic than either B or C
18. In this structure, what is the relationship between the groups P and Q?



- gauche
 - anti
 - eclipsed
 - none of these
19. In the structure in #18, what is the relationship between T and R?
- gauche
 - anti
 - eclipsed
 - none of these

20. Here is a Newman projection of a cyclohexane showing a group "X" as one of the substituents. To the right is a chair with several substituents labeled. The front carbons in the Newman projection are indicated with dots, and the point of view of the observer (you) is also indicated.

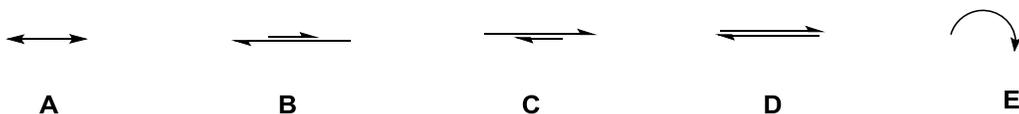
Which substituent in the chair corresponds to X in the Newman projection?



21. Calculate the barrier to rotation, in kcal/mol, around the C2-C3 bond in 2-methylbutane. Use the following energy values:

Interaction	Energy (kcal/mol)
H-H eclipse	1.0
CH ₃ -H eclipse	1.3
CH ₃ -CH ₃ eclipse	4.1

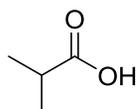
- a. 2.5
 b. 4.8
 c. 3.9
 d. 5.6
 e. 6.4
22. Select the symbol that best describes the relationship between reactants and products for the proton transfer reaction between ammonia and water.



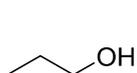
23. In the reaction described in #22, the HOMO is

- a. Nonbonding MO in ammonia
- b. N-H σ^*
- c. Nonbonding MO in water
- d. O-H σ^*
- e. None of these

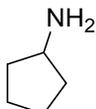
24. Which of these compounds has an acid strength closest to that of water?



A



B



C



D



E

25. Miley Cyrus was recently observed “twerking” vigorously. A crowd of horrified and disgusted onlookers gathered and began shouting things like, “Go away! Please, just go away!” Miley defended herself by stating that she was merely accessing different conformations. If Miley were *really* accessing different conformations while twerking, which of these statements would have to be true?

- a. Miley would be rotating around her sigma bonds.
- b. Miley would be stabilizing her conjugate base through resonance.
- c. Miley would be experiencing an inductive effect based on the presence of a fluorine atom attached to her tongue (ugh).
- d. Miley would be accepting a proton.