

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

1 H																	2 He	
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne	
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr	
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe	
55 Cs	56 Ba	57-70 *	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-102 **	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uu	111 Uu	112 Uu	114 Uuq					

\* Lanthanide series

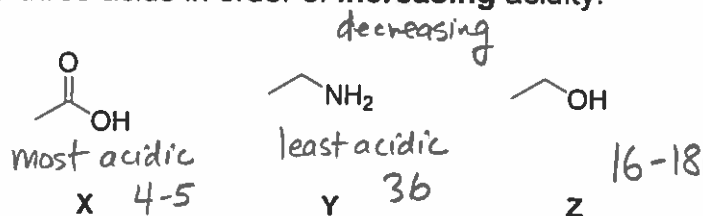
57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

\*\* Actinide series

**Potentially useful information:**

$pK_a$  values:  $H_3O^+$ , -1.7       $NH_4^+$ , 9       $CH_3CH_2OH$ , 16       $CH_3OH_2^+$ , -2

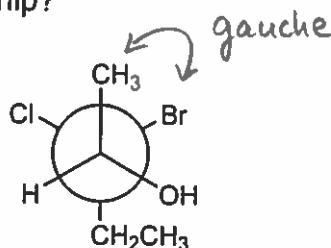
1. Arrange the three acids in order of **increasing** acidity.



- C
- a.  $X > Y > Z$
  - b.  $Z > Y > X$
  - c.  $X > Z > Y$
  - d.  $Y > Z > X$
  - e.  $Y > X > Z$



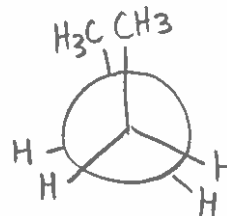
2. In this Newman projection, which of the following pairs of groups does not represent an anti relationship?



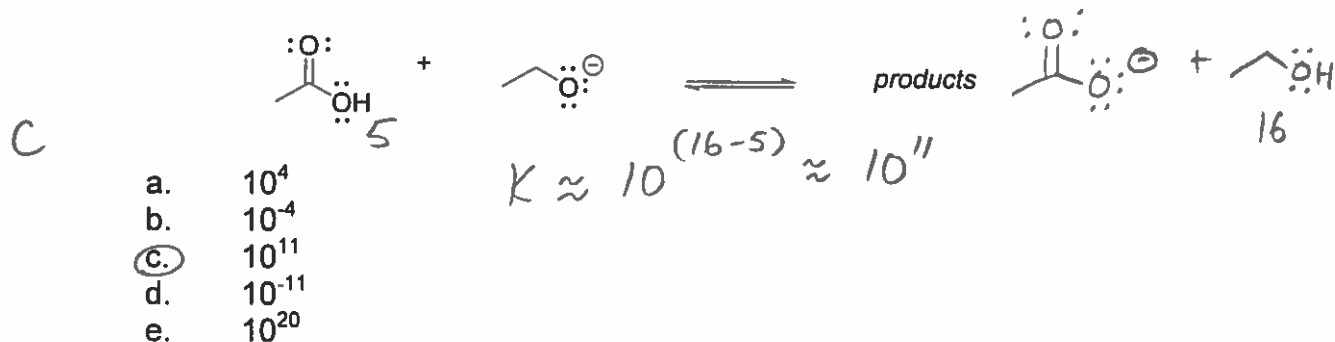
- A
- a.  $CH_3$  and Br
  - b. H and Br
  - c. Cl and OH
  - d.  $CH_3$  and  $CH_2CH_3$
  - e. All of the listed pairs are in an anti relationship

3. What type of strain is present in the **highest energy** conformer of butane?

- D
- a. Torsional
  - b. van der Waals
  - c. Angle
  - d. Torsional and van der Waals
  - e. There is no strain in that conformer



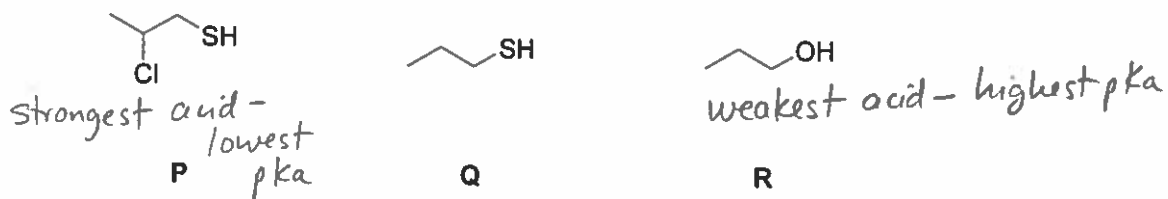
4. A proton transfer (Bronsted acid-base reaction) occurs between the two compounds shown. (The spectator ion is omitted for clarity.) Select the number that is the **best estimate** of the equilibrium constant for this reaction.



5. The **base** in the reaction in #4 is a/an:

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

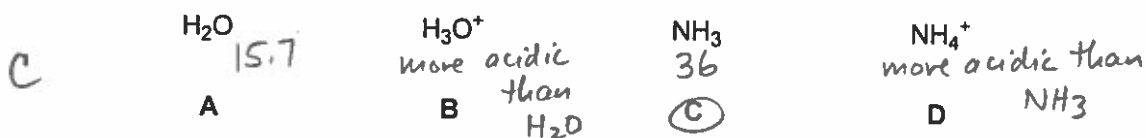
6. Arrange the three acids in order of **decreasing**  $pK_a$ .



- B
- a.  $P > Q > R$   
 b.  $R > Q > P$   
 c.  $R > P > Q$   
 d.  $P > R > Q$   
 e.  $Q > R > P$

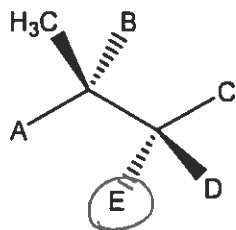


7. Select the **weakest** acid.



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

E



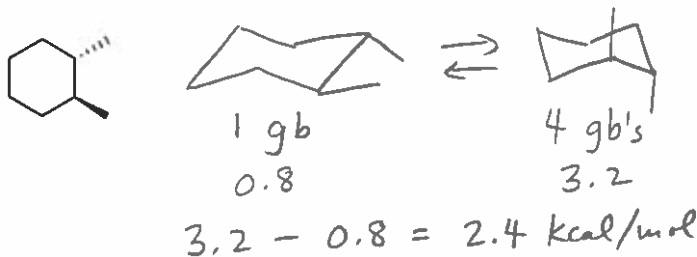
9. Select the weakest acid.

B

- a. H<sub>2</sub>O 15.7  
 b. CH<sub>4</sub> weaker than NH<sub>3</sub>  
 c. NH<sub>3</sub> 36.0  
 d. HBr Strong acid  
 e. CH<sub>3</sub>OH 15-16

10. What is the approximate difference in energy between the two chair conformations of this molecule?

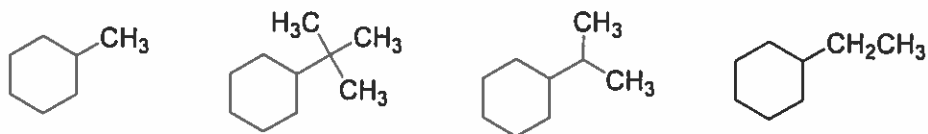
C



- a. 0.8 kcal/mol  
 b. 1.6 kcal/mol  
 c. 2.4 kcal/mol  
 d. 3.2 kcal/mol  
 e. There is no energy difference between the two chair conformers.

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

A



(A)

Smallest alkyl group

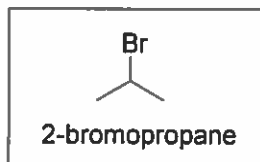
B

C

D

Largest alkyl group - this would have the greatest preference for the equatorial position

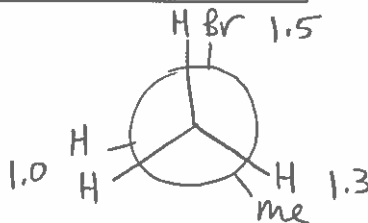
12. Use the table of energies provided to calculate the strain energy of the highest energy conformation of 2-bromopropane looking down C1-C2.



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

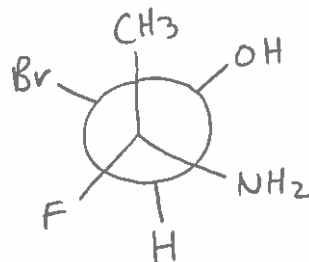
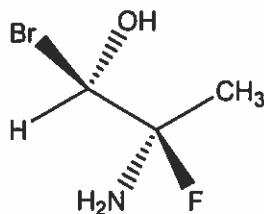
B

- 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



$$1.0 + 1.5 + 1.3 = 3.8$$

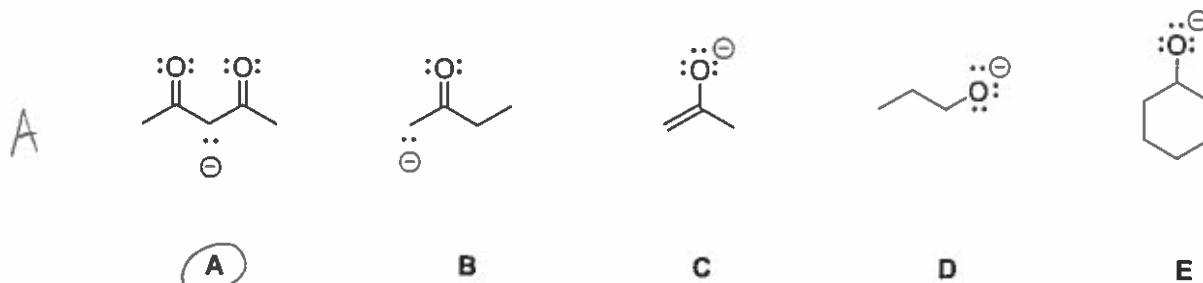
13. Which of these numbers is closest to the value of the torsion angle between OH and CH<sub>3</sub> in this conformer?



C

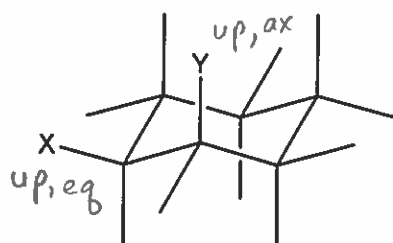
- a. 30°  
 b. 45°  
 c. 60°  
 d. 109.5°  
 e. 180°

14. Select the weakest base.



Has the most acceptable resonance contributors

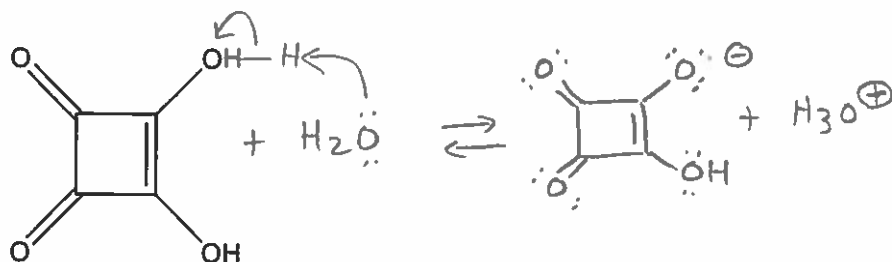
15. In this chair structure, substituents "X" and "Y" are:



Both up = cis  
One axial, one equatorial  
on adjacent C's: gauche

- 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?

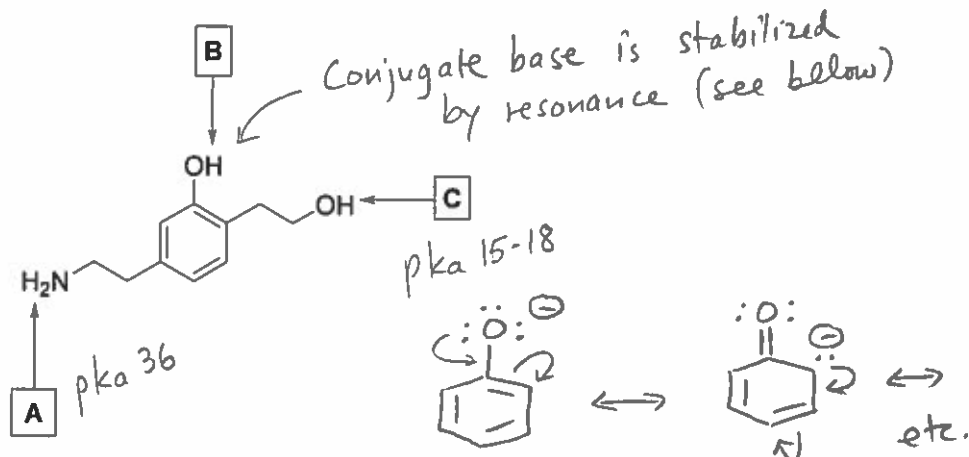


squaric acid

- a. O-H  $\sigma$
- b. O-H  $\sigma^*$
- c. C-O  $\pi$
- d. Nonbonding MO in water
- e. None of these

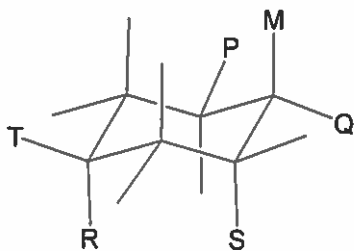
17. A molecule may have more than one acidic hydrogen atom. Using your knowledge of the factors influencing acidity, which of the indicated hydrogen atoms in this molecule is **most acidic**? (Notice that "A" refers to either of the protons attached to N.)

B



- a. A  
 b. B  
 c. C  
 d. All the indicated protons are equally acidic  
 e. 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?



A

- a. gauche Equatorial, on adjacent carbons  
 b. anti  
 c. eclipsed  
 d. none of these

19. In the structure in #18, what is the relationship between T and R?

- a. gauche  
 b. anti  
 c. eclipsed  
 d. none of these

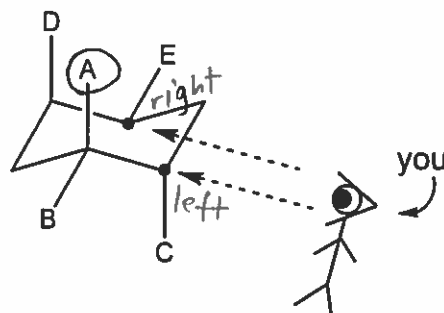
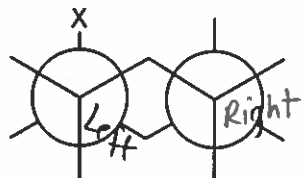
D

T and R are on the same carbon, so no torsion angle

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?

A



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

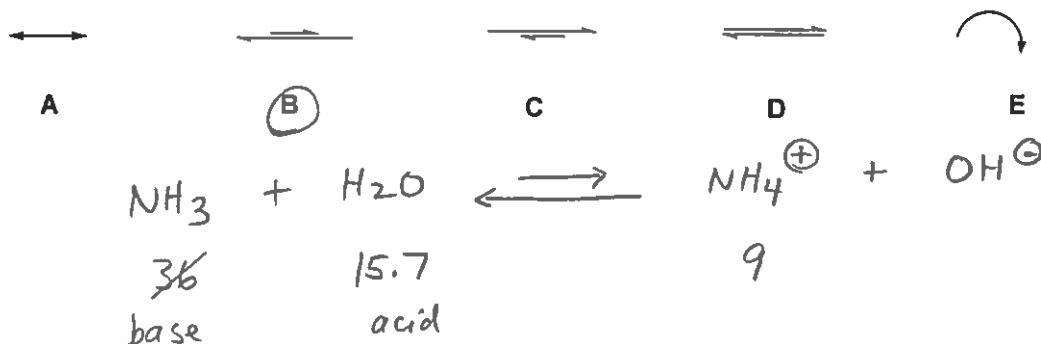
Interaction	Energy (kcal/mol)
H-H eclipse	1.0
CH <sub>3</sub> -H eclipse	1.3
CH <sub>3</sub> -CH <sub>3</sub> eclipse	4.1

- a. 2.5  
 b. 4.8  
 c. 3.9  
 d. 5.6  
 e. 6.4

See next page →

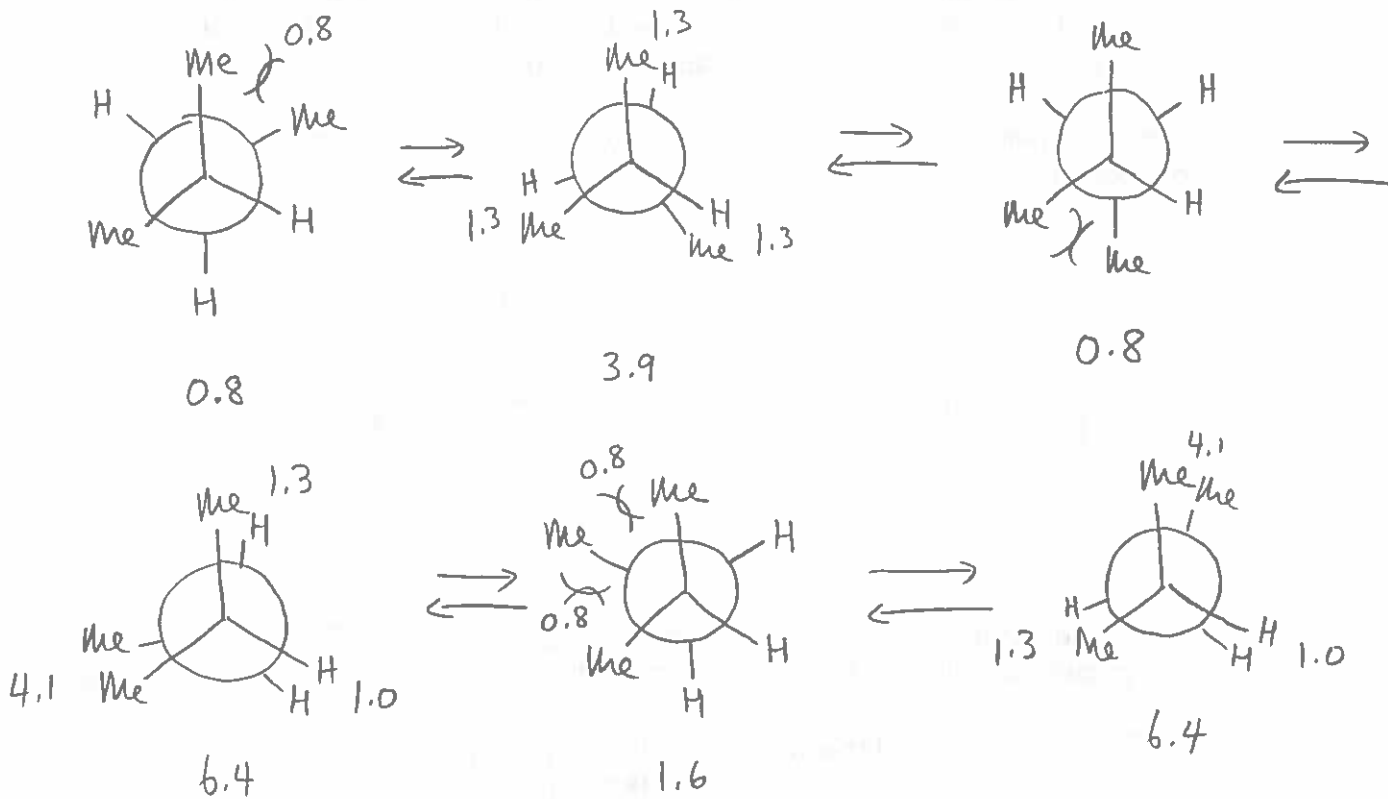
22. Select the symbol that best describes the relationship between reactants and products for the proton transfer reaction between ammonia and water.

B





2-methyl butane 



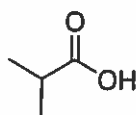
23. In the reaction described in #22, the HOMO is

A

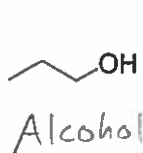
- a. Nonbonding MO in ammonia
- b. N-H  $\sigma^*$
- c. Nonbonding MO in water
- d. O-H  $\sigma^*$
- e. None of these

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

B

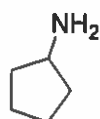


A



Alcohol

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

- 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.