

Key

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 1.008																	2 He 4.002				
3 Li 6.941	4 Be 9.012															5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305															13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.887	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.64	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80				
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc [98]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29				
55 Cs 132.91	56 Ba 137.33	57-70 * Lanthanide series	71 Lu 174.967	72 Hf 178.49	73 Ta 180.948	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.967	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [209]	85 At [210]	86 Rn [222]			
87 Fr [223]	88 Ra [226]	89-102 ** Actinide series	103 Lr [260]	104 Rf [261]	105 Db [262]	106 Sg [263]	107 Bh [264]	108 Hs [265]	109 Mt [266]	110 Uun [267]	111 Uuu [268]	112 Uub [269]									

\* Lanthanide series

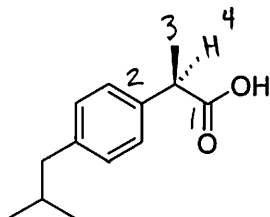
57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

\*\* Actinide series

1. Ibuprofen is a commonly used pain reliever called an NSAID (non-steroidal anti-inflammatory drug). Its *S* enantiomer is more biologically active; however, an enzyme in our bodies converts the *R* enantiomer into the *S* enantiomer so the medication may be administered as a racemic mixture.

Which enantiomer is this?

A



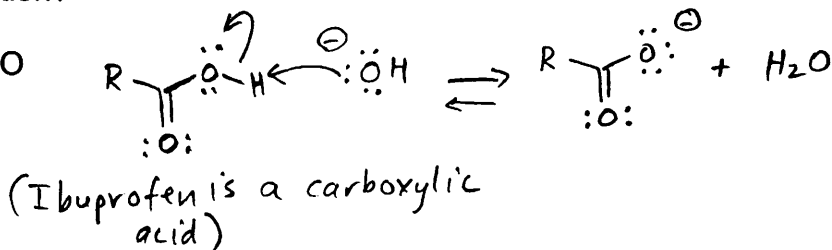
Ibuprofen

- (a) *R*  
b. *S*

2. Refer to the structure of ibuprofen in question 1. When ibuprofen is treated with the strong base sodium hydroxide, a proton transfer occurs. What is the LUMO in the reaction?

C

- a. Nonbonding MO  
b. O-H  $\sigma$   
(c) O-H  $\sigma^*$   
d. *p*  
e. C-H  $\sigma^*$



3. When ibuprofen reacts with sodium hydroxide as described in question 2, what is the HOMO in the reaction?

A

- (a) Nonbonding MO  
b. O-H  $\sigma$   
c. O-H  $\sigma^*$   
d. *p*  
e. C-H  $\sigma^*$

4. What is the approximate difference in energy between the two chair conformations of cis-1,2-dimethylcyclohexane?

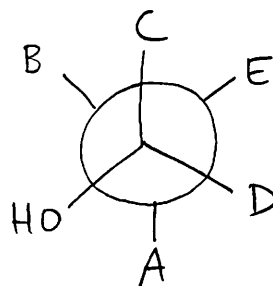
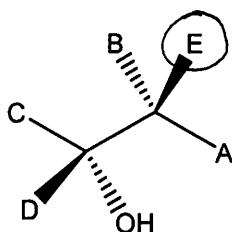
E

- 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.



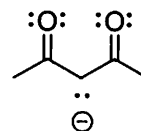
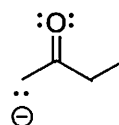
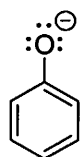
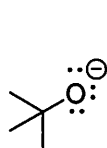
5. In the structure shown, which of the indicated groups is **anti** to the OH group?

E



6. Select the **strongest** base.

A



(All the others are resonance stabilized.)

**A**

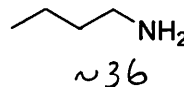
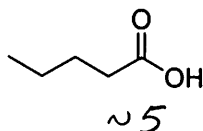
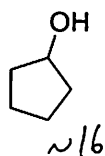
B

C

D

E

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



W

X

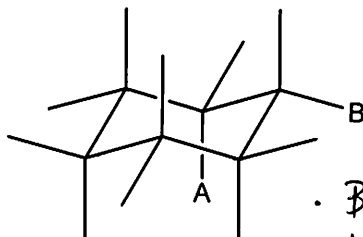
Y

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

Y > W > X  
 highest pKa > lowest pKa

C

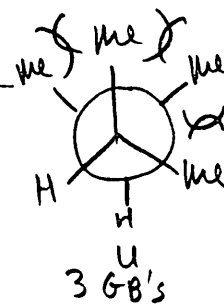
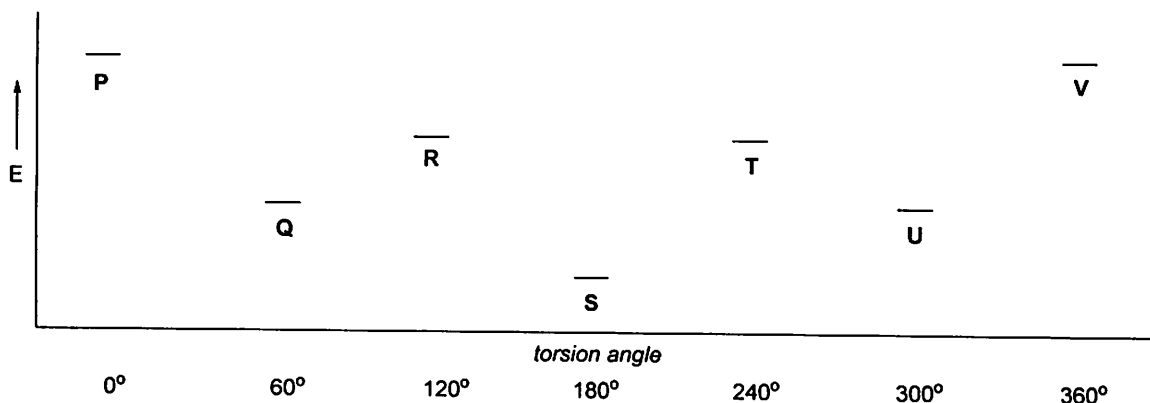
8. In this chair structure, substituents "A" and "B" are:



• Both "down" → cis  
 • Ax and eq on adjacent ring C's → gauche

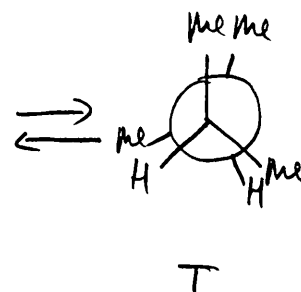
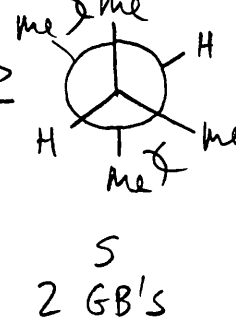
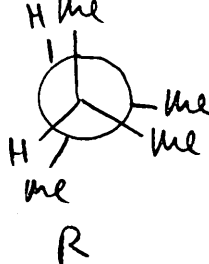
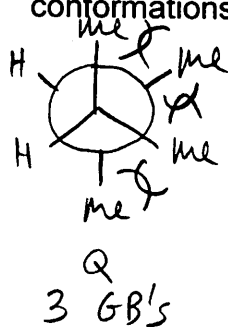
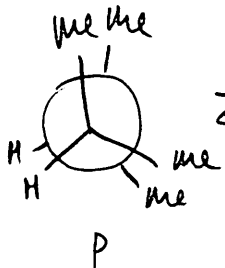
- a. anti and trans  
 b. anti and cis  
 c. gauche and trans  
**d.** gauche and cis  
 e. none of these

9. Consider the different conformations of 2,3-dimethylbutane looking down the C2-C3 bond. The relative energies of the conformations are plotted for you below as a function of torsion (dihedral) angle:



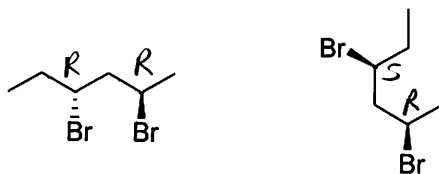
Which of these conformers or pairs of conformers has the **greatest** number of gauche butane interactions?

- a. P and V  
**b.** Q and U  
 c. R and T  
 d. S  
 e. There are no gauche butane interactions in any of the conformations.



↑↓

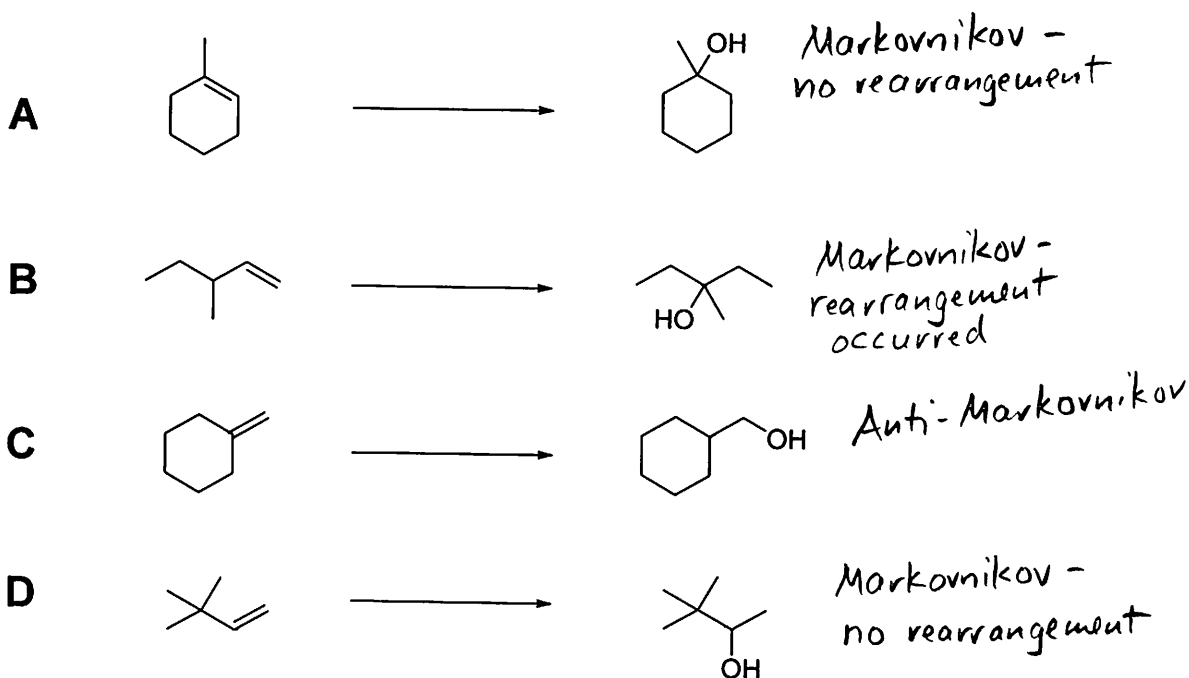
10. What is the relationship between these two structures?



B

- a. Constitutional isomers
- b. Diastereomers**
- c. Enantiomers
- d. Identical
- e. None of the above

For questions 11-13, refer to the list of reactions shown here. Some answer choices may be used more than once, or not at all.



C 11. Which reaction has an anti-Markovnikov alcohol as the product?

B 12. In which reaction did a carbocation rearrangement occur?

A 13. For which reaction could you use EITHER of these conditions to give the product shown as the major product?

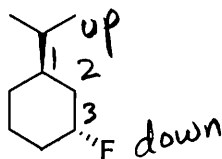
Hg(OAc)<sub>2</sub>/H<sub>2</sub>O, then NaBH<sub>4</sub> OR H<sub>2</sub>SO<sub>4</sub>(cat.)/H<sub>2</sub>O } (Both are Markovnikov conditions, ruling out "C")

Treating "D" with acid and water would result in a rearranged product.

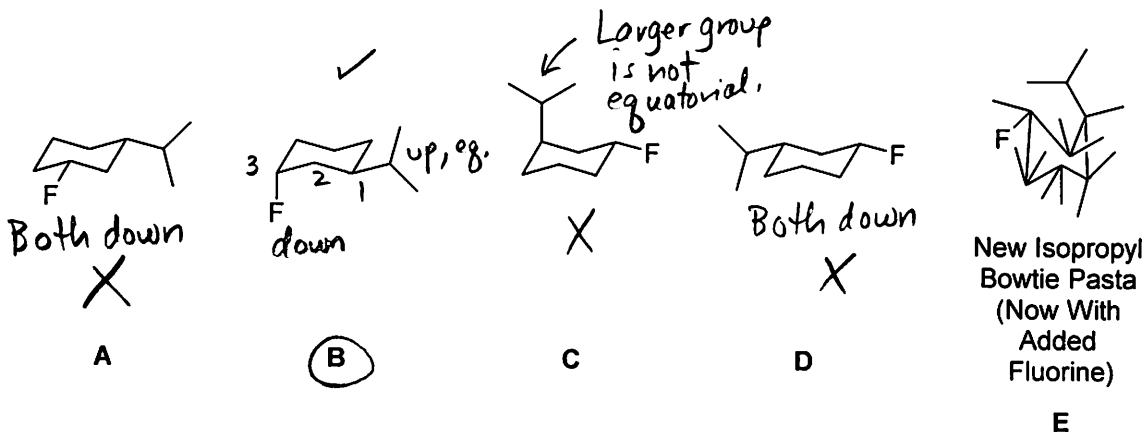
Treating "B" with oxymercuration-demercuration would not give the product shown.

14. The "A" value ( $\Delta G$ ) for an isopropyl group is 2.1, and for a fluorine atom it is 0.25. Select the most stable conformation of this molecule from the choices given.

Larger A value  $\rightarrow$  more preference for equatorial position



B



15. How many stereoisomers are there for 1,2-dimethylcyclopropane?

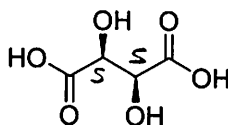
C

- a. 1  
b. 2  
c. 3  
d. 4



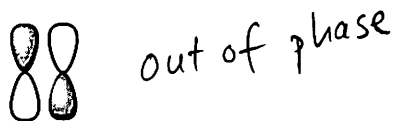
16. Here is one of the stereoisomers of tartaric acid, a naturally occurring compound found in grapes and bananas. Which of these terms is the best description of this structure?

C



- a. Achiral  
b. Achiral and meso  
c. Chiral

17. Which of these orbitals forms when two carbon  $p$  orbitals, one on each carbon atom, combine in the manner shown here?



D

- a.  $\sigma$
- b.  $\sigma^*$
- c.  $\pi$
- d.  $\pi^*$

18. What is the label for the orbital shown in question 17?

B

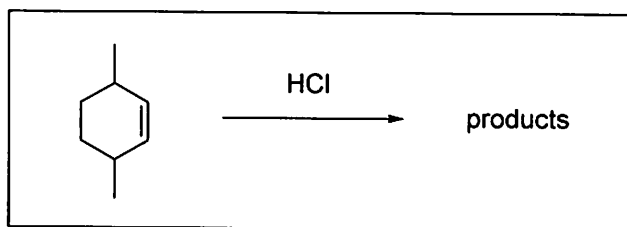
- a. Bonding
- b. Antibonding
- c. Nonbonding

19. Water is

C

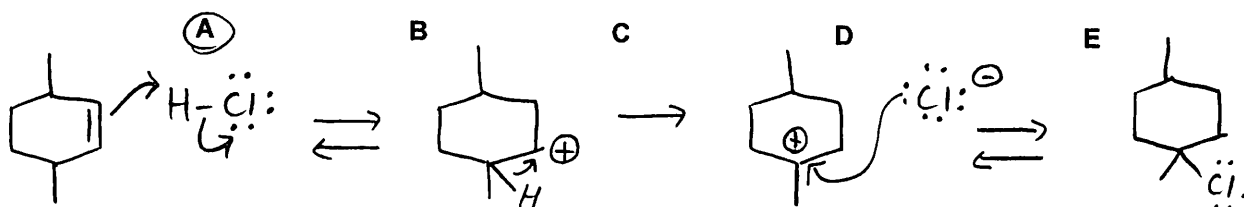
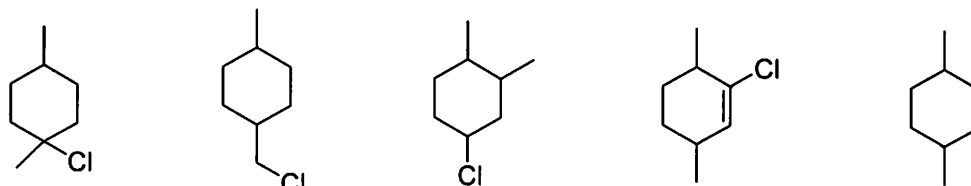
- a. a weak acid
- b. a weak base
- c. both a and b
- d. neither a nor b

20. Consider the following reaction conditions:



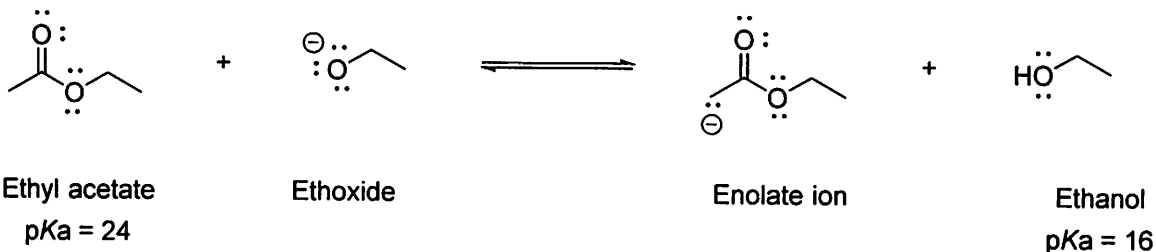
A

Which of these structures is the most likely **major product** of the reaction?



Questions 21-23 refer to the reaction shown in question 20.

21. Consider the following acid-base (proton transfer) reaction. Chemical names and  $pK_a$  values are provided. Spectator ions are omitted for clarity.



A

Which side of the reaction is favored at equilibrium?

- a. Reactants  
 b. Products  
 c. Neither reactants nor products (i.e.,  $K_{eq} = 1$ )

22. What is the approximate  $K_{eq}$  for the reaction?  
(product acid  $pK_a$  - reactant acid  $pK_a$ )

A

- a.  $10^{-8}$   
 b.  $10^8$   
 c. 8  
 d. 1

$$K_{eq} \approx 10^{(16-24)} = 10^{-8}$$

23. Still referring to the reaction in question 20, which is a stronger base: ethoxide or the enolate ion?

B

- a. Ethoxide  
 b. Enolate ion  
 c. They have equal base strength  
 d. Cannot be determined from information provided

Stronger acid + stronger base are on one side of equation, weaker acid + weaker base are on the other side.

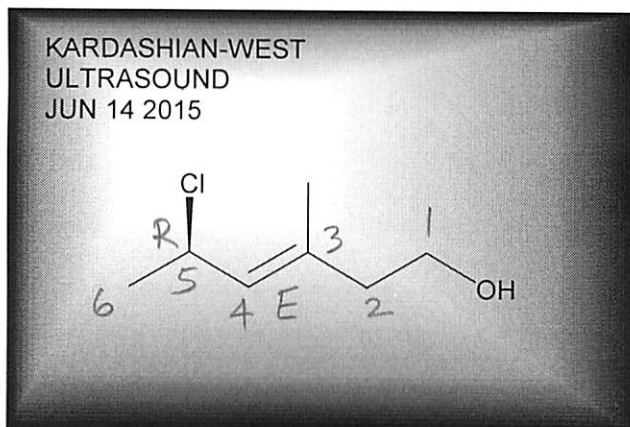
24. Breaking a bond is an \_\_\_\_\_ process.

A

- a. endothermic  
 b. exothermic



25. Kim Kardashian and Kanye West are having another baby! An ultrasound examination showed that the baby looks like this:



Although both parents are secretly very concerned that the baby does not resemble either one of them, Kim wants to call the baby “Khiral Kardashian”, while Kanye thinks that the child should be named “Gauche West”. However, IUPAC, the society of chemists that establishes naming rules, has insisted that the child be given a proper chemical name.

What should be the correct name of the child, according to IUPAC?

- a. (3*E*, 5*R*)-5-chloro-3-methyl-3-hexen-1-ol  
b. (2*R*, 3*E*)-2-chloro-4-methyl-3-hexen-6-ol  
c. (3*E*, 5*S*)-5-chloro-3-methyl-3-hexen-1-ol  
d. (2*S*, 3*E*)-2-chloro-4-methyl-3-hexen-6-ol  
e. None of these choices is the correct name of the “child”.