

Please read Honor Code statement below
and sign your Scantron in the box on front:

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.

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 signed Scantron. You may keep the exam to check your answers against the key later.

Good luck!

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

Hydrogen 1 H 1.00794																	Helium 2 He 4.00260				
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 32.06	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 47.88	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 58.69	Copper 29 Cu 63.546	Zinc 30 Zn 65.38	Gallium 31 Ga 69.723	Germanium 32 Ge 72.64	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 101.07	Palladium 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 126.905	Xenon 54 Xe 131.29				
Cesium 55 Cs 132.91	Barium 56 Ba 137.33	* 57-70	Lanthanum 57 La 138.905	Hafnium 72 Hf 178.49	Tantalum 73 Ta 180.948	Tungsten 74 W 183.84	Rhenium 75 Re 186.21	Osmium 76 Os 190.23	Iridium 77 Ir 192.22	Platinum 78 Pt 195.084	Gold 79 Au 196.967	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	Lanthanide series	Rutherfordium 103 Rf [261]	Dubnium 104 Db [262]	Seaborgium 105 Sg [266]	Bhassium 106 Bh [264]	Hassium 107 Hs [277]	Mtensium 108 Mt [276]	Ununennium 109 Uue [288]	Ununennium 110 Uuu [288]	Ununennium 111 Uub [289]	Ununennium 112 Uuq [289]	Ununennium 114 Uuq [289]							

* Lanthanide series

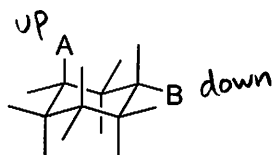
57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
138.91	140.12	140.91	144.24	[145]	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.05

* Actinide series

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
[227]	232.04	231.04	238.03	[237]	[244]	[243]	[247]	[247]	[251]	[252]	[257]	[258]	[259]

1. Select any and all true statements about this structure:

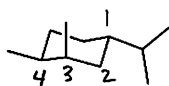
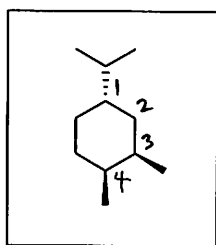
B



- a. The groups A and B are cis.
b. The groups A and B are trans.
 c. The groups A and B are gauche.
 d. The groups A and B are anti.
 e. More than one of these statements is true.
- } These terms do not apply since the bonds to A and B are not on adjacent carbons.

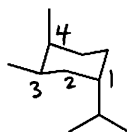
2. Select the structure that represents the *less* stable chair conformation of the molecule in the box.

C

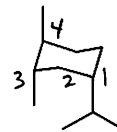


A

Not same as molecule B in box

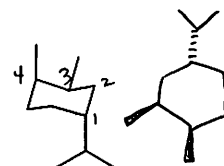


C



D

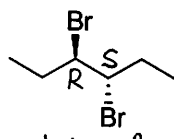
This is



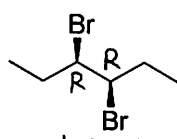
E

This is the enantiomer of the molecule in the box.

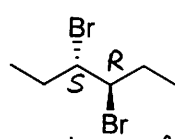
Questions 3, 4, 5 and 6 all relate to the following set of structures.



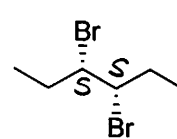
achiral & meso
W



chiral
X



achiral & meso
Y



chiral
Z

3. Which of these structures is/are chiral?

A

- a.** X and Z
 b. W and Y
 c. Only X
 d. Only W
 e. All four structures are chiral

4. Which of these structures are achiral and meso?

B

- a. X and Z
- b. W and Y
- c. Only X
- d. Only W
- e. All four structures are achiral and meso

5. Which of these pairs are enantiomers?

D

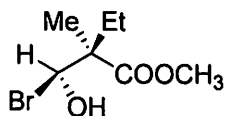
- a. W and X
- b. W and Y
- c. W and Z
- d. X and Z
- e. Both b and d

6. Which of these pairs are identical?

B

- a. W and X
- b. W and Y
- c. W and Z
- d. X and Z
- e. Both b and d

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

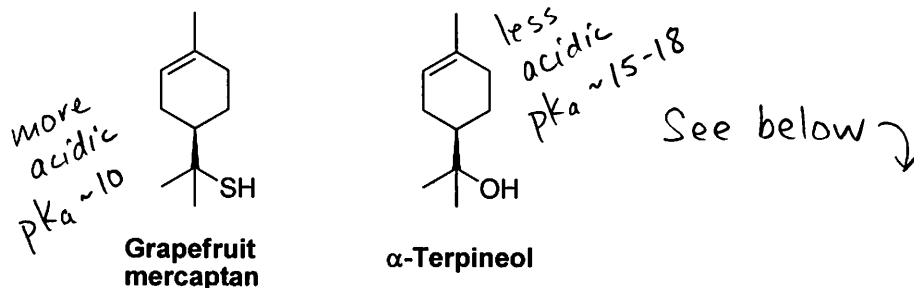


D

- a. H
- b. Br
- c. Me
- d. Et
- e. COOCH₃

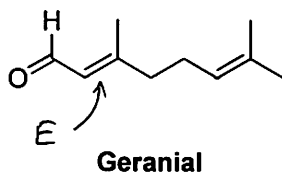
8. Grapefruit mercaptan (pK_a 10) is a natural product found in grapefruit. Alpha-terpineol is another natural product found in a variety of plant sources and used in perfumery. When each of these compounds is treated with sodium hydroxide, a proton transfer occurs. Which reaction has the larger equilibrium constant?

A



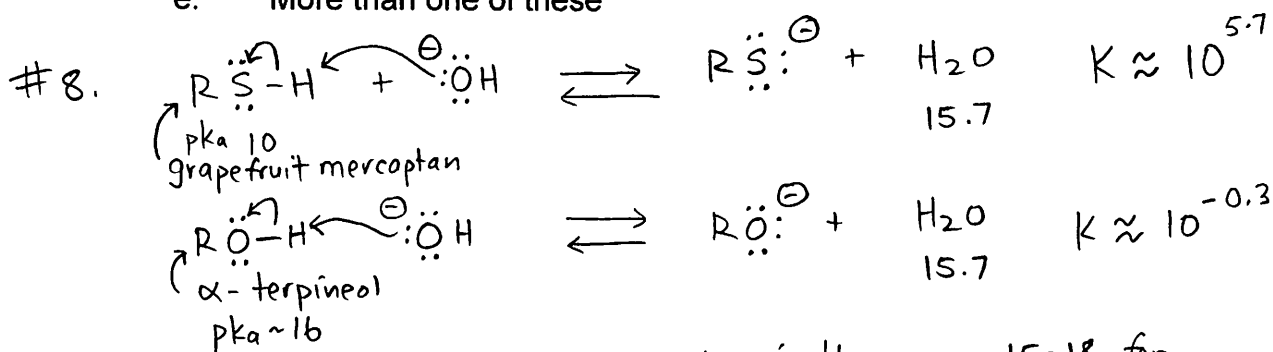
- a. The reaction of sodium hydroxide and grapefruit mercaptan
 b. The reaction of sodium hydroxide and α -terpineol
 c. Both reactions will have roughly the same equilibrium constant
 d. There is not enough information available to answer the question
9. Geranial is a natural product that is a component of the oils of various plants. Which of the following stereochemical labels will appear in the IUPAC name for geranial?

C



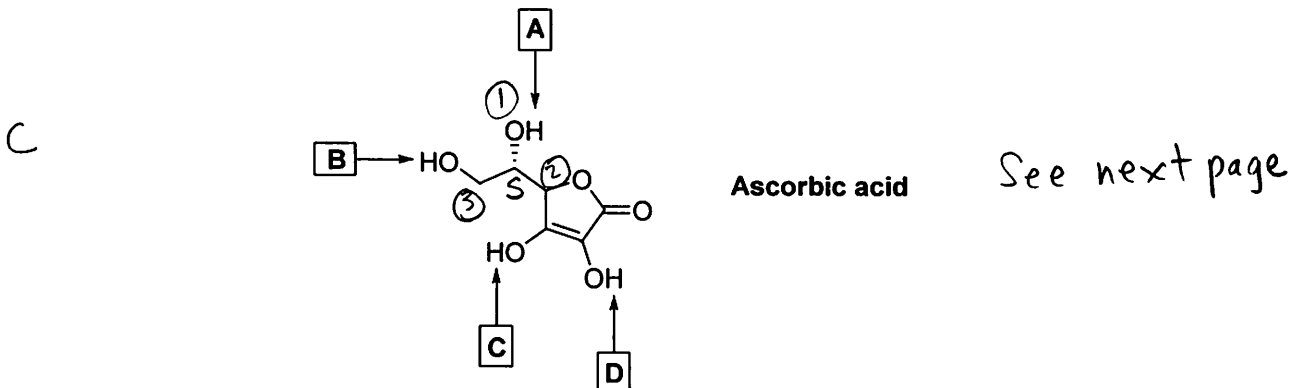
- There are no asymmetric carbons in geranial
- Only one of the alkenes can be designated as E or Z

- a. R
 b. S
 c. E
 d. Z
 e. More than one of these



(You could use any value in the range 15-18 for the alcohol and all will show a K with a negative power of 10.)

10. Ascorbic acid is one form of Vitamin C. Four of its protons are labeled in the structure below. Which of these protons is most acidic?



11. In the structure of ascorbic acid in question 10, proton "A" is part of a hydroxyl (OH) group that is attached to an asymmetric carbon. What is the absolute configuration at this asymmetric carbon?

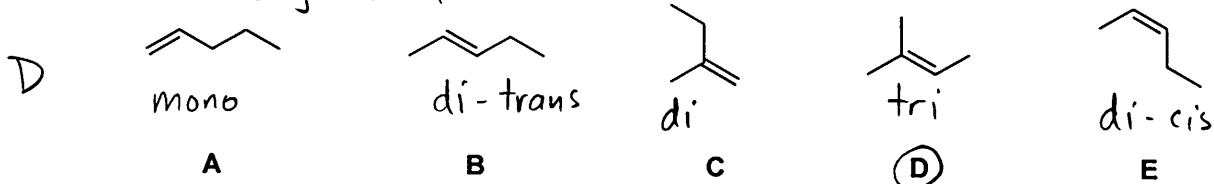
B

a. R
 (b.) S

See structure

12. Which of these alkene isomers is most stable?

Degrees of substitution noted:



13. Two of the alkene isomers in question 12, when treated with sulfuric acid and water, will give the same product. Which two?

B

a. A and B
 (b.) C and D
 c. B and E
 d. A and D
 e. C and E

single

See next page

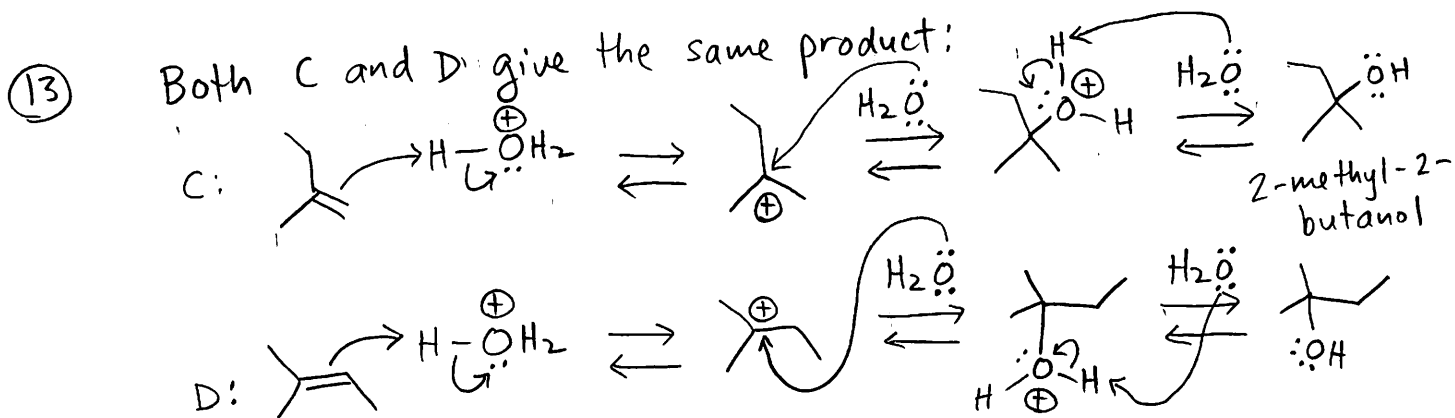
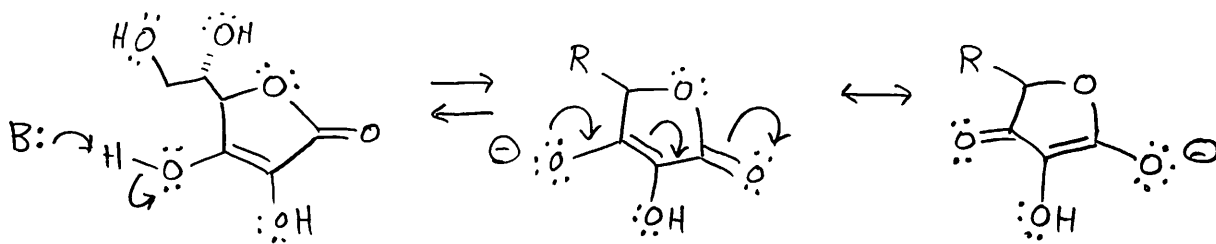
14. Two of the alkene isomers in question 12, when treated with HBr, would give a mixture of products rather than only one product. Which two?

C

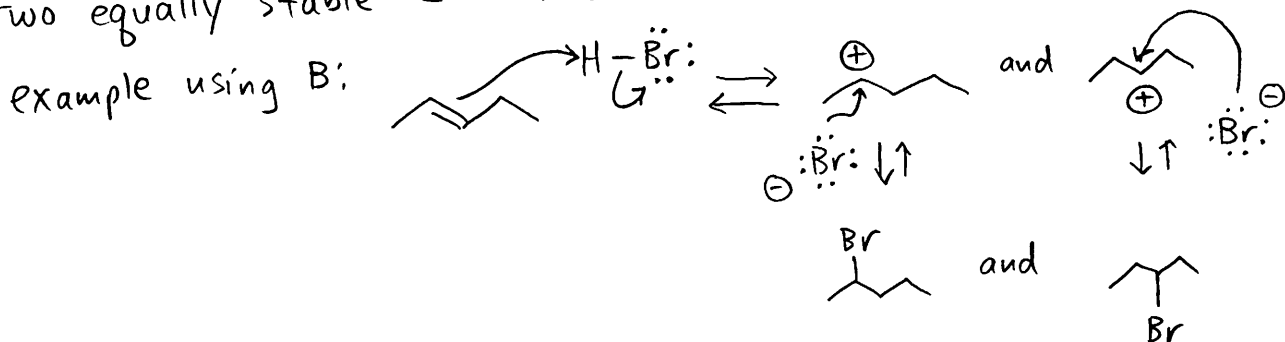
a. A and B
 b. C and D
 (c.) B and E
 d. A and D
 e. C and E

See next page

- ⑩ All four protons are attached to oxygen atoms, but only the conjugate base produced by removing "c" has resonance stabilization involving delocalization of \ominus to another O:

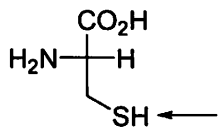


- ⑭ For each of the disubstituted alkenes B and E, two equally stable 2° carbocations can be produced:

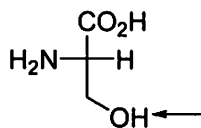


resulting in a mixture of products

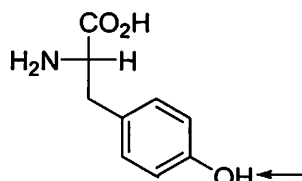
15. Here are three amino acids, drawn as Fischer projections:



cysteine



serine



tyrosine

less acidic than tyrosine (CB not res. stabilized) or cysteine (S larger than O)

B

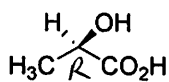
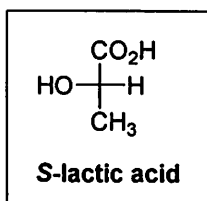
In each structure, the proton on the amino acid's "side chain" is designated with an arrow. In which of these amino acids is the side chain least acidic?

- a. Cysteine
- b. Serine
- c. Tyrosine
- d. All three are equally acidic

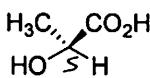
16. S-Lactic acid, a chiral compound, is produced during normal metabolism and exercise. Which of these molecules, when combined with S-lactic acid, could produce a racemic mixture?

Its enantiomer

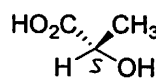
A



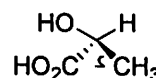
A



B

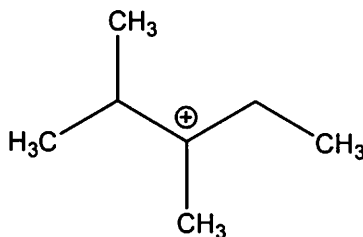


C



D

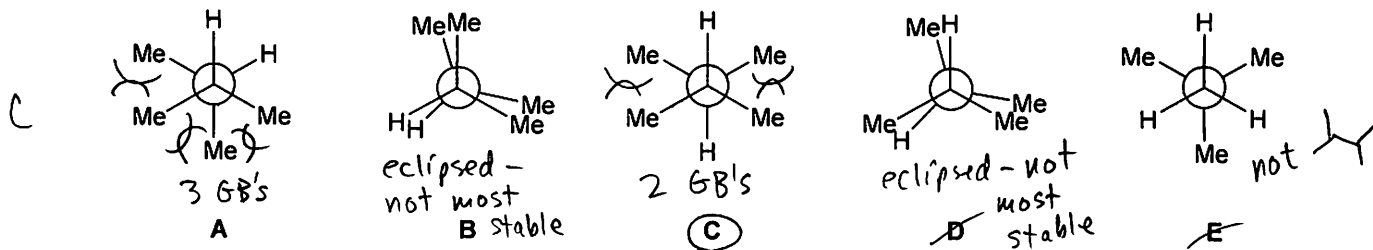
17. Hyperconjugation is one of the ways that carbocations can be stabilized. Which of the following pairs of orbitals is/are NOT participating in this type of stabilization for the carbocation shown below?



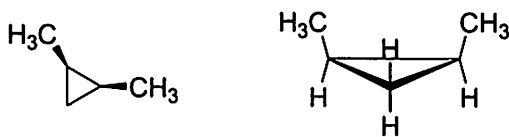
C

- a. C-H σ and p
 - b. C-C σ and p
 - c. C-H σ^* and p — Both are empty
 - d. Both a and b
 - e. a, b, and c
- Each represents filled bonding MO + empty p (definition of hyperconjugation)

18. Which of these Newman projections shows the most stable conformation of 2,3-dimethylbutane looking down the C2-C3 bond?

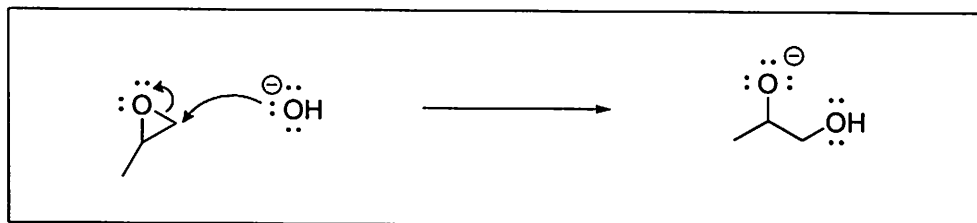


19. What types of strain do you expect to be present in this molecule? The structure is drawn in two different ways to help you visualize.



- a. Torsional
 b. van der Waals - the 2 Me's
 c. Angle
 d. Torsional and angle
 e. All three types of strain

20. Here is a reaction that you will see shortly:



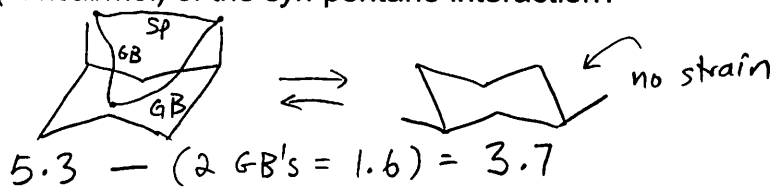
In this reaction, hydroxide ion is acting as a nucleophile and attacking an epoxide (the electrophile). This causes the three-membered ring to open. What is the LUMO in this process? (Lewis acid)

- a. Nonbonding MO in hydroxide ion
 b. OH σ
 c. CO σ
 d. CO σ^* (C-O bond is breaking; thus the antibonding orbital is involved.)
 e. Nonbonding MO or p orbital in the epoxide
- Base uses HOMO
 Acid uses LUMO

21. We saw in class that one example of a 1,3-diaxial interaction is when there are two axial methyl groups on the same side of a cyclohexane ring, called a *syn* pentane interaction. For *cis*-1,3-dimethylcyclohexane, the difference in energy between the two chair conformations is 5.3 kcal/mol. Given that the energy of a gauche butane interaction is 0.8 kcal/mol, what is the energy value (in kcal/mol) of the *syn* pentane interaction?

C

- a. 2.1
 b. 2.9
 c. 3.7
 d. 4.5
 e. Cannot be determined with the available information

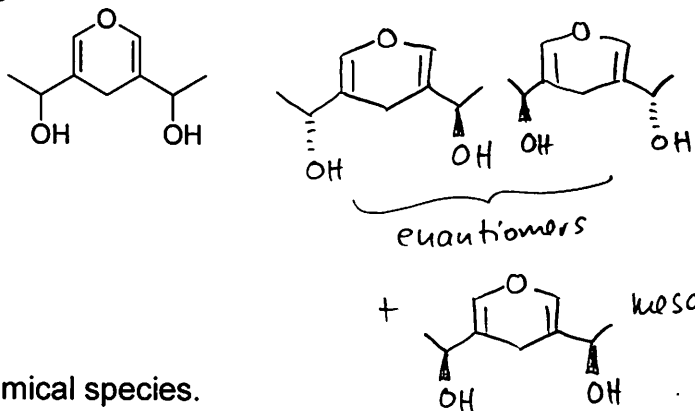


22. How many stereoisomers exist for this constitution?

2 asymmetric C's

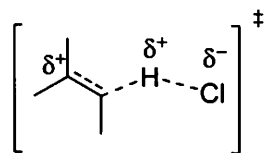
C

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

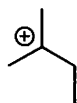


23. Select the least stable chemical species.

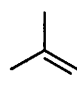
A



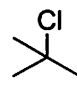
(A)



B



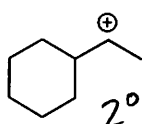
C



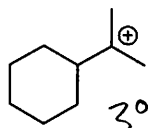
D

24. Select the least stable carbocation.

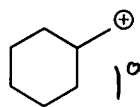
C



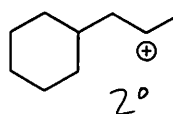
A



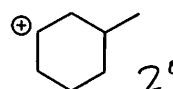
B



(C)



D

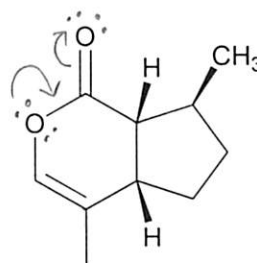
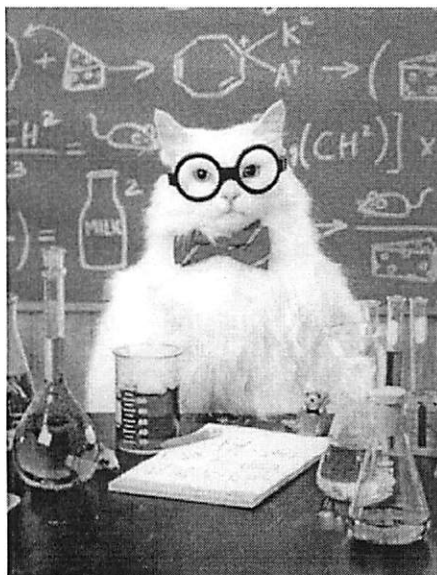


E

25. Recently, in a concert in Canada, Justin Bieber fell off the stage. Here is a direct quotation from the news article reporting this fact: "During the 22-year-old pop star's Saskatchewan, Canada concert, he fell right off the edge of the stage while adjusting his pants between songs." (You can't make this stuff up.)

Authorities suspect that someone placed an intoxicating substance in Bieber's energy drink, which resulted in his tumble off the stage. The prime suspect is the Chemistry Cat. It is believed that the Chemistry Cat secretly spiked Bieber's drink with a massive dose of nepetalactone, the active ingredient in catnip, and that Bieber had an unfavorable reaction to this compound.

Which statement best describes the hybridization of the oxygen atoms in nepetalactone? (Lone pairs are not explicitly drawn; all atoms are neutral.)



Recall resonance delocalization in esters!

nepetalactone

- a. Both are sp^2 hybridized
b. Both are sp^3 hybridized
c. The carbonyl oxygen is sp^2 and the ester oxygen is sp^3
d. The carbonyl oxygen is sp^3 and the ester oxygen is sp^2