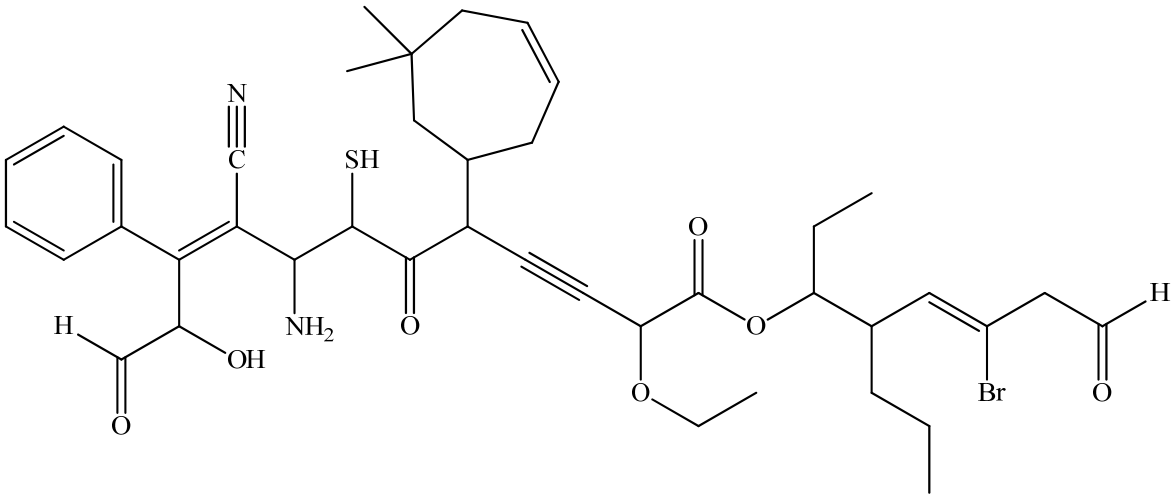
Chem 201 Midterm
Spring, 2014 Name _____
Beauchamp

Problems	Points	Credit
1. Functional Group Nomenclature	30	
2. Degrees of Unsaturation & Functional Groups or Various Nomenclature Terms	20	
3. 2D structure, Functional Groups	20	
4. 2D / 3D Resonance Structures, Formal Charge	25	
5. Simple 2D Resonance Structures, Formal Charge	15	
6. Physical Properties, Forces of Interaction	15	
7. Cyclohexane Conformations, Substituents, Energy, K_{eq}.	25	
8. Newman Projections, Open Chain Structure, Relative Energies, K_{eq}.	25	
9. Stereochemical Analysis	30	
Total	205	

This is a long exam. It has been designed so that no one question will make or break you. The best strategy is to work steadily, starting with those problems you understand best. Make sure you show all of your work. Draw in any lone pairs of electrons, formal charge and curved arrows to show electron movement where appropriate. I give partial credit, so writing down anything that you know is correct will be helping yourself. Do your best to show me what you know in the time available.

The only way of finding the limits of the possible is by going beyond them into the impossible. - Arthur C. Clarke

1. Provide an acceptable name for the following molecule. (30 pts)



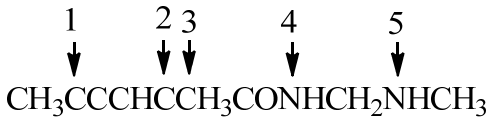
2. Use the given molecular formula to calculate the degree of unsaturation. Draw an example molecule that has the indicated functional groups. (20 pts)

   $C_{27}H_{23}BrClN_3O_{12}S$ functional groups: nitrile, carboxylic acid, anhydride, thiol, amide, ester, alcohol, alkyne, alkene, aldehyde, ketone, bromo, aromatic, acid chloride, amine

3. Draw an acceptable Lewis structure (2D) for the following formula. Show <u>all</u> single, double and triple bonds with one, two or three lines. Include all lone pairs of electrons as two dots. Include formal charge, if present, at the atom where present. Identify any functional groups by name (i.e. ketone, amide, etc.) (20 pts)

$(CH_3)_2CHCOC(CH_3)CHCCCO_2CH(CN)CHNH_2CH(OCH_3)CONHC_6H_4CH(CHO)CHOHCO_2H$

4. First draw the best 2D Lewis structure of the following molecule. Draw a correct 3D structure. Show bonds in front of the page as wedges, bonds in back of the page as dashed lines and bonds in the page as simple lines. Show orbital representations for pi bonds and lone pairs along with their electrons. Fill in the informational table at the bottom for the numbered atoms. (25 pts)



2D

3D

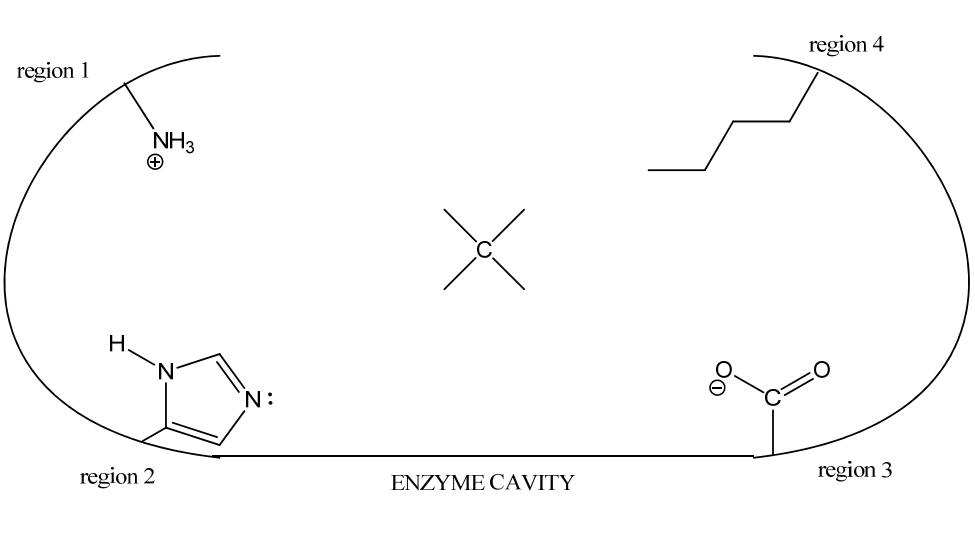
Atom	Shape	Hybridization	Bond Angles	#σ bonds	#π bonds	# lone pairs
1						
2						
3						
4						
5						

5. Draw all reasonable 2D resonance structures for the following structures. Assume full octets for all nonhydrogen atoms unless there is a positive charge written. Use correct arrows, formal charge and include lone pairs. (15 pts)

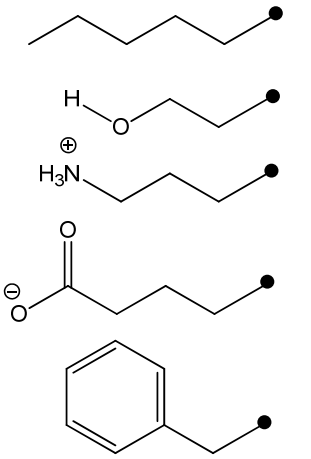
a. $H_2CCHCHOH^{\oplus}$

b. OOO

6. The active site of an important liver enzyme has just been discovered. Four key regions are shown in the enzyme cavity, just below. As an employee of Bronco Pharmaceutical, you are trying to design an inhibitor molecule that will strongly bind to the key regions of the active site so that the normal substrate cannot get in and react. You have a variety of branches that you can attach to a central sp^3 carbon atom. Pick appropriate branches to maximize enzyme binding, and show how your molecule will sit in the enzyme cavity. Give a very brief explanation for why each branch has its special affinity. (15 pts)



Available Branches, (acidic or basic groups are drawn as they would appear at the body's pH)



7. Draw all possible chair conformations of cis-1-bromo-2-isopropylcyclohexane. Draw in all axial and equatorial atoms in each chair. Draw the more stable conformation first. Draw Newman projections of both conformations using the $C_1 \rightarrow C_2$ and $C_5 \rightarrow C_4$ bonds or the $C_2 \rightarrow C_1$ and $C_4 \rightarrow C_5$ bonds to sight along. Point out any gauche interactions of the substituents shown in your Newman projections. Assume any gauche interaction of side chain groups is 0.8 kcal/mole, combined with any axial energy values (see table below) to determine the relative energies of each conformation. Use those energies to determine the relative percents. Sketch an energy diagram that shows how the energy changes with the conformational changes. Assume a single high energy boat transition state, TS (you do not have to draw the boat) (25 pts)

Given Information

Substituent	ΔG^o (A value)	Substituent	ΔG^o (A value)
-H	0.0	-F	0.3
$-CH_3$	1.7	-Cl	0.5
$-CH_2CH_3$	1.8	-Br	0.5
$-CH(CH_3)_2$	2.1	-I	0.5
$-C(CH_3)_3$	> 5.0	$-C_6H_5$ (phenyl)	2.9

chair 1 $\rightleftharpoons$ chair 2

$$K = \frac{\text{chair 2}}{\text{chair 1}} = 10^{\frac{-\Delta G}{2.3RT}}$$

R = 2 cal/(mole-K)
T ≈ 300 K

chair 1
(most stable)

cis-1-bromo-2-isopropylcyclohexane

chair 2
(less stable)

boat
transition
state

Newman projections:

$C_1 \rightarrow C_2$ and $C_5 \rightarrow C_4$

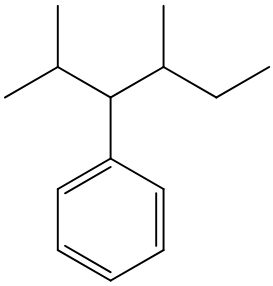
or

$C_2 \rightarrow C_1$ and $C_4 \rightarrow C_5$

$$K = \frac{\text{chair 2}}{\text{chair 1}} = 10^{\frac{-\Delta G}{2.3RT}} =$$

Energy changes of cis-1-bromo-2-isopropylcyclohexane conformations.

8. Use a Newman projection of the C3→C4 bond of 2,4-dimethyl-3-phenylhexane to **show the most stable conformation first**. Also show the highest energy conformation. Using the energy values provided in the table below, calculate the relative energies of the different conformations. Use this energy to calculate a ratio of these isomers. Plot the changes in energy in the graph diagram provided. Hint: First "bold" the bond viewed in your 2D structure and then decide your line of sight. On the final exam you will have to draw all 6 conformations. (25 pts)



2,4-dimethyl-3-phenylhexane

$\Delta G \approx \Delta H$

$K_{eq} = 10^{\frac{-\Delta H}{2.3RT}}$

Approximate Eclipsing Energy Values (kcal/mole)

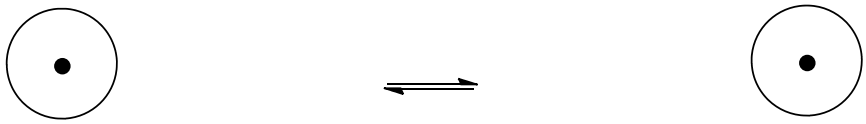
	H	Me	Et	i-Pr	t-Bu	Ph
H	1.0	1.4	1.5	1.6	3.0	1.7
Me	1.4	2.5	2.7	3.0	8.5	3.3
Et	1.5	2.7	3.3	4.5	10.0	3.8
i-Pr	1.6	3.0	4.5	7.8	13.0	8.1
t-Bu	3.0	8.5	10.0	13.0	23.0	13.5
Ph	1.7	3.3	3.8	8.1	13.5	8.3

Approximate Gauche Energy Values (kcal/mole)

	H	Me	Et	i-Pr	t-Bu	Ph
H	0	0	0.1	0.2	0.5	0.2
Me	0	0.8	0.9	1.1	2.7	1.4
Et	0.1	0.9	1.1	1.6	3.0	1.5
i-Pr	0.2	1.1	1.6	2.0	4.1	2.1
t-Bu	0.5	2.7	3.0	4.1	8.2	3.9
Ph	0.2	1.4	1.5	2.1	3.9	2.3

most stable conformation

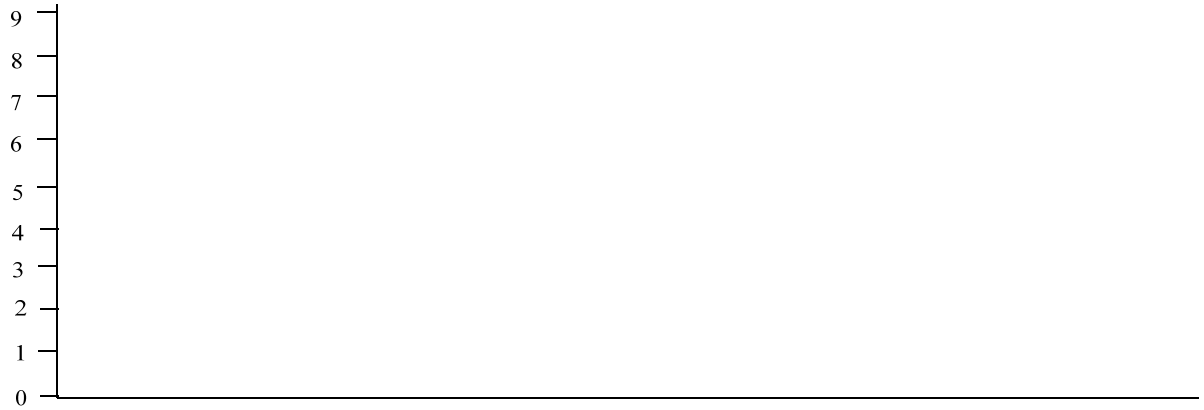
least stable conformation



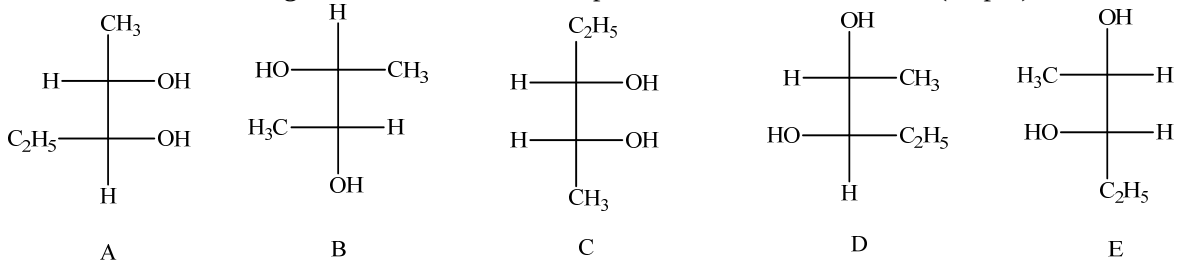
$K_{eq} = 10^{\frac{-\Delta H}{2.3RT}} =$

$\Delta H^o =$

$\Delta H^o =$



9. For the following set of Fischer projections answer each of the questions below by circling the appropriate letter(s) or letter combination(s). Hint: Redraw the Fischer projections with the longest carbon chain in the vertical direction and having similar atoms in the top and bottom portion. Classify all chiral centers in the first structure as R or S absolute configuration and write an acceptable name for that isomer. (30 ptx)



a. Which are optically active? A B C D E

b. Which are meso? A B C D E

c. Which is not an isomer with the others? A B C D E

d. Which pairs are enantiomers? AB AC AD AE BC BD BE CD CE DE

e. Which pairs are identical? AB AC AD AE BC BD BE CD CE DE

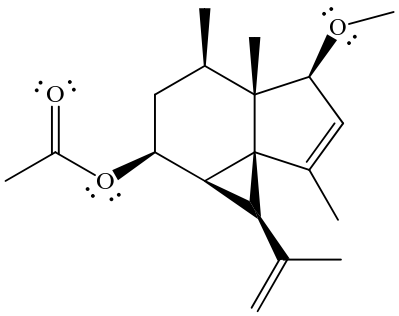
f. Which pairs are diastereomers? AB AC AD AE BC BD BE CD CE DE

g. Which pairs, when mixed in equal amounts will not rotate plane polarized light? AB AC AD AE BC BD BE CD CE DE

h. Draw any stereoisomers of pentane-2,3-diol as Fischer projections, which are not shown above. If there are none, indicate this.

i. Would anything change if, in compound B, the OH was replaced with a NH_2 group?

j. The structure of Shagene A is shown below. It is one of two related compounds recently isolated from choral (Org. Lett., ASAP, April 29, 2014). Circle all stereogenic centers in following molecule and calculate the maximum number of stereoisomers possible.



maximum number
of stereoisomers = _____

Humans are not prisoners of fate, but only prisoners of their own minds. - Franklin D. Roosevelt

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Spring, 2014 Name _____Key_____
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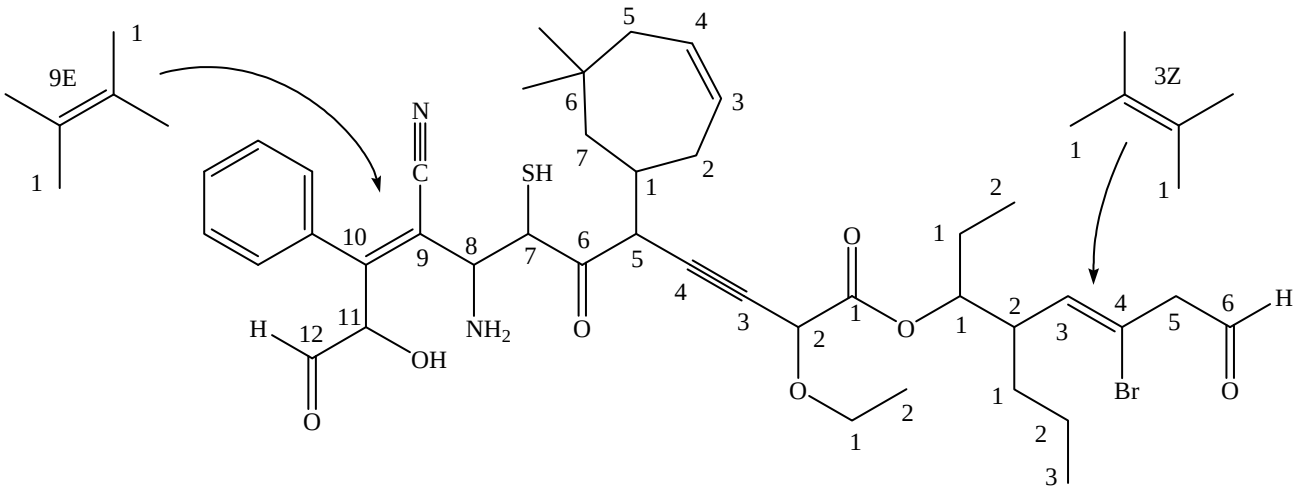
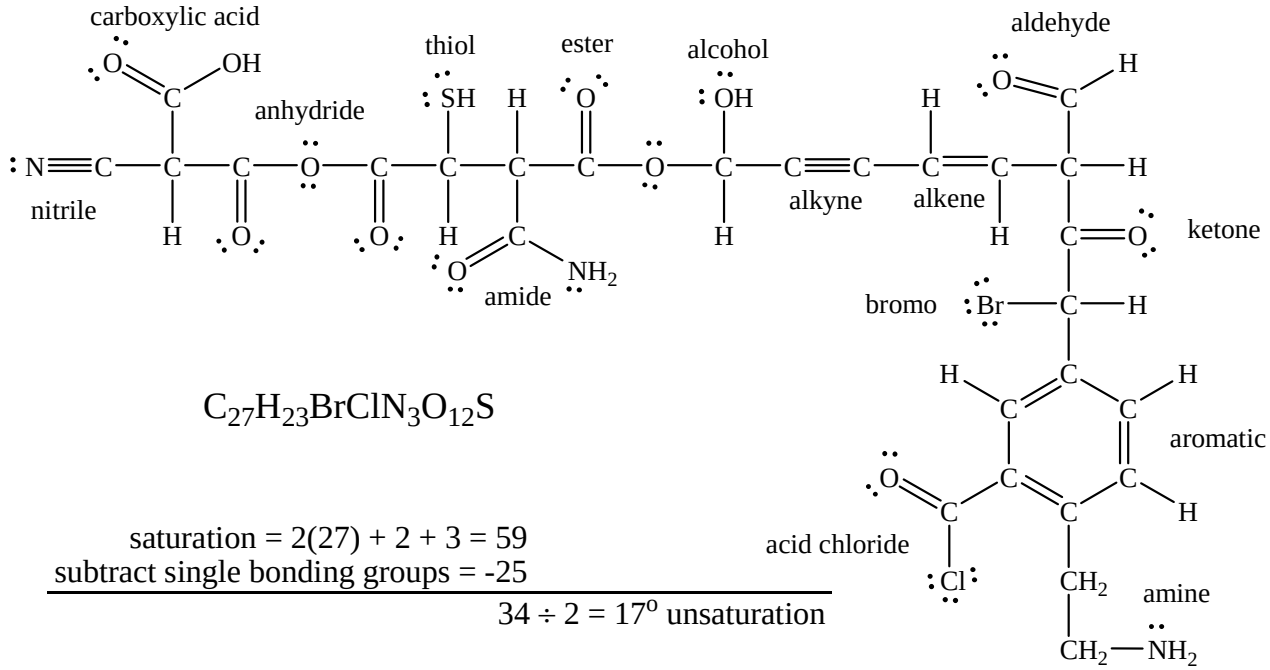
1. Provide an acceptable name for the following molecule. (30 pts)



1-ethyl-2-propyl-4-bromo-6-oxohex-3Z-enyl 2-ethoxy-5-(6,6-dimethylcyclohept-3-enyl)-6,12-dioxo-7-mercapto-8-amino-9-cyano-10-phenyl-11-hydroxydodec-9E-en-3-ynoate

2. Use the given molecular formula to calculate the degree of unsaturation. Draw an example molecule that has the indicated functional groups. (20 pts)

$C_{27}H_{23}BrClN_3O_{12}S$ functional groups: nitrile, carboxylic acid, anhydride, thiol, amide, ester, alcohol, alkyne, alkene, aldehyde, ketone, bromo, aromatic, acid chloride, amine



$C_{27}H_{23}BrClN_3O_{12}S$

saturation = 2(27) + 2 + 3 = 59
subtract single bonding groups = -25

34 ÷ 2 = 17° unsaturation

3. Draw an acceptable Lewis structure (2D) for the following formula. Show <u>all</u> single, double and triple bonds with one, two or three lines. Include all lone pairs of electrons as two dots. Include formal charge, if present, at the atom where present. Identify any functional groups by name (i.e. ketone, amide, etc.) (20 pts)

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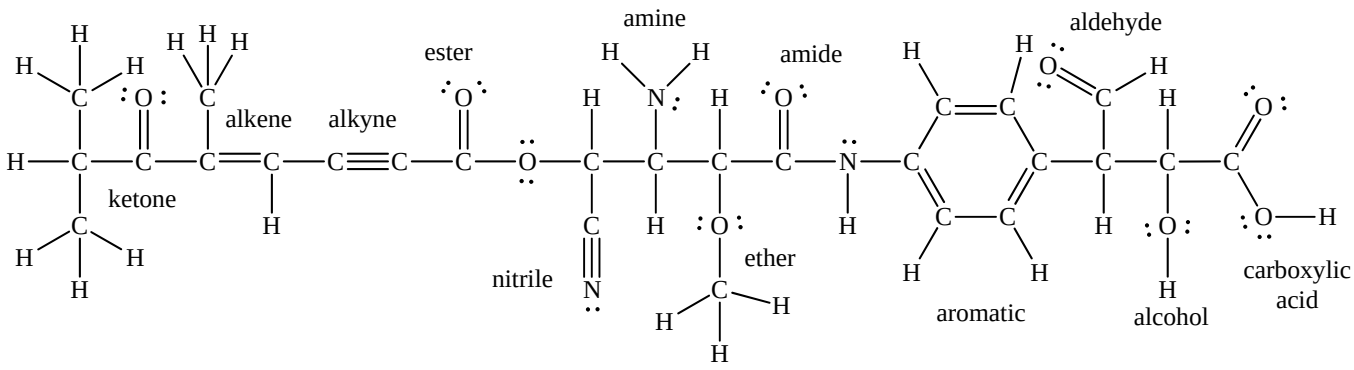

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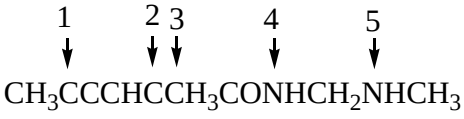
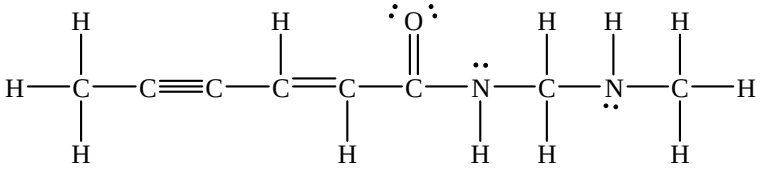
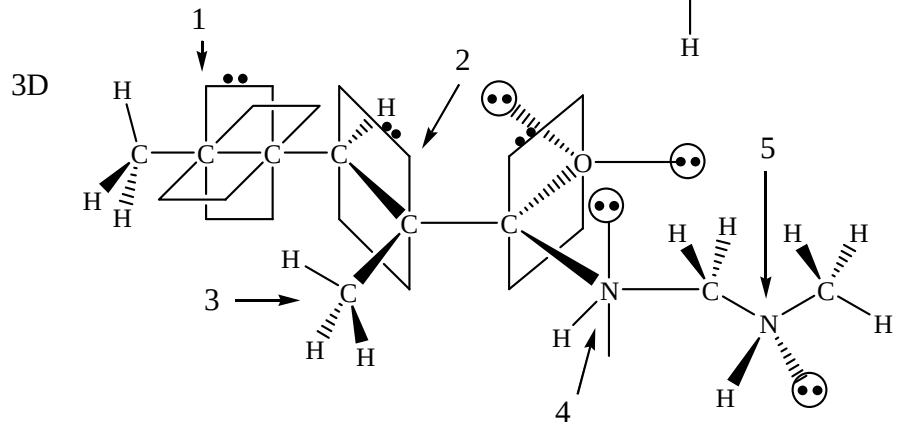


2D



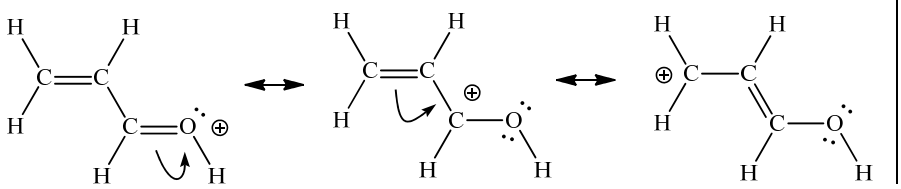
3D



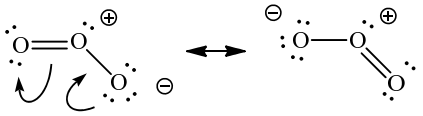
Atom	Shape	Hybridization	Bond Angles	#σ bonds	#π bonds	# lone pairs
1	sp	linear	180°	2	2	0
2	sp^2	trigonal planar	120°	3	1	0
3	sp^3	tetrahedral	109°	4	0	0
4	sp^2	trigonal planar	120°	3	0	1
5	sp^3	tetrahedral	109°	3	0	1

5. Draw all reasonable 2D resonance structures for the following structures. Assume full octets for all nonhydrogen atoms unless there is a positive charge written. Use correct arrows, formal charge and include lone pairs. (15 pts)

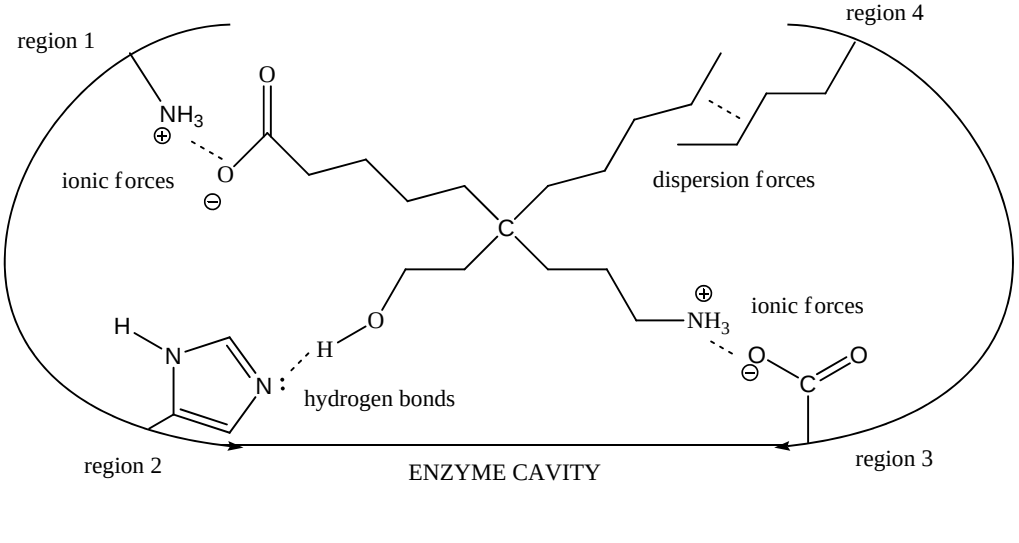
a. $H_2CCHCHOH^{\oplus}$



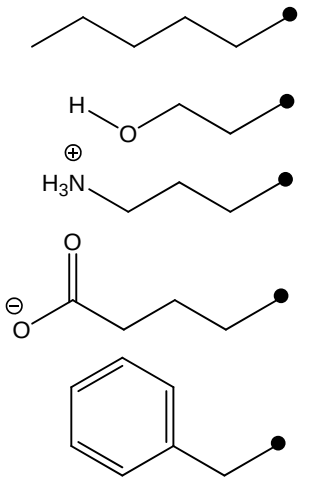
b. OOO



6. The active site of an important liver enzyme has just been discovered. Four key regions are shown in the enzyme cavity, just below. As an employee of Bronco Pharmaceutical, you are trying to design an inhibitor molecule that will strongly bind to the key regions of the active site so that the normal substrate cannot get in and react. You have a variety of branches that you can attach to a central sp^3 carbon atom. Pick appropriate branches to maximize enzyme binding, and show how your molecule will sit in the enzyme cavity. Give a very brief explanation for why each branch has its special affinity. (15 pts)



Available Branches, (acidic or basic groups are drawn as they would appear at the body's pH)



7. Draw all possible chair conformations of cis-1-bromo-2-isopropylcyclohexane. Draw in all axial and equatorial atoms in each chair. Draw the more stable conformation first. Draw Newman projections of both conformations using the $C_1 \rightarrow C_2$ and $C_5 \rightarrow C_4$ bonds or the $C_2 \rightarrow C_1$ and $C_4 \rightarrow C_5$ bonds to sight along. Point out any gauche interactions of the substituents shown in your Newman projections. Assume any gauche interaction of side chain groups is 0.8 kcal/mole, combined with any axial energy values (see table below) to determine the relative energies of each conformation. Use those energies to determine the relative percents. Sketch an energy diagram that shows how the energy changes with the conformational changes. Assume a single high energy boat transition state, TS (you do not have to draw the boat) (25 pts)

Given Information

Substituent	ΔG^o (A value)	Substituent	ΔG^o (A value)
-H	0.0	-F	0.3
$-CH_3$	1.7	-Cl	0.5
$-CH_2CH_3$	1.8	-Br	0.5
$-CH(CH_3)_2$	2.1	-I	0.5
$-C(CH_3)_3$	> 5.0	$-C_6H_5$ (phenyl)	2.9

chair 1 $\rightleftharpoons$ chair 2

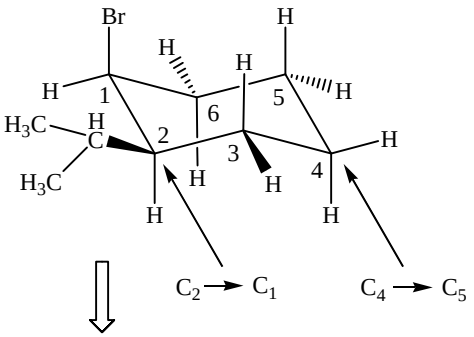
$$K = \frac{\text{chair 2}}{\text{chair 1}} = 10^{\frac{-\Delta G}{2.3RT}}$$

R = 2 cal/(mole-K)
T ≈ 300 K

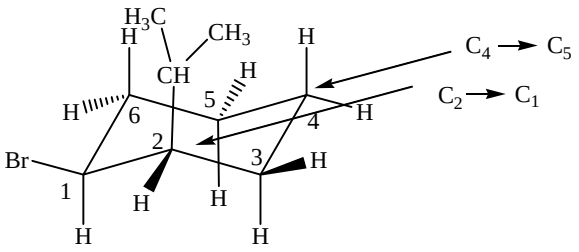
chair 1
(most stable)

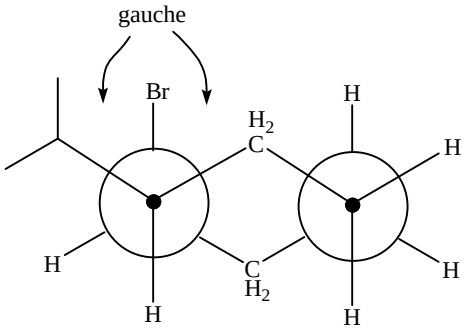
cis-1-bromo-2-isopropylcyclohexane

chair 2
(less stable)

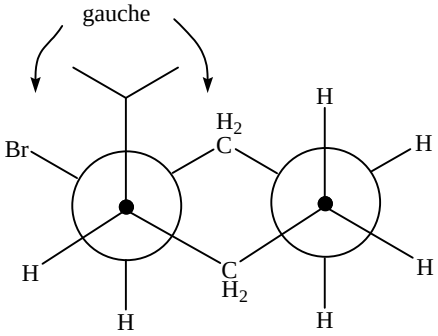


boat
transition
state





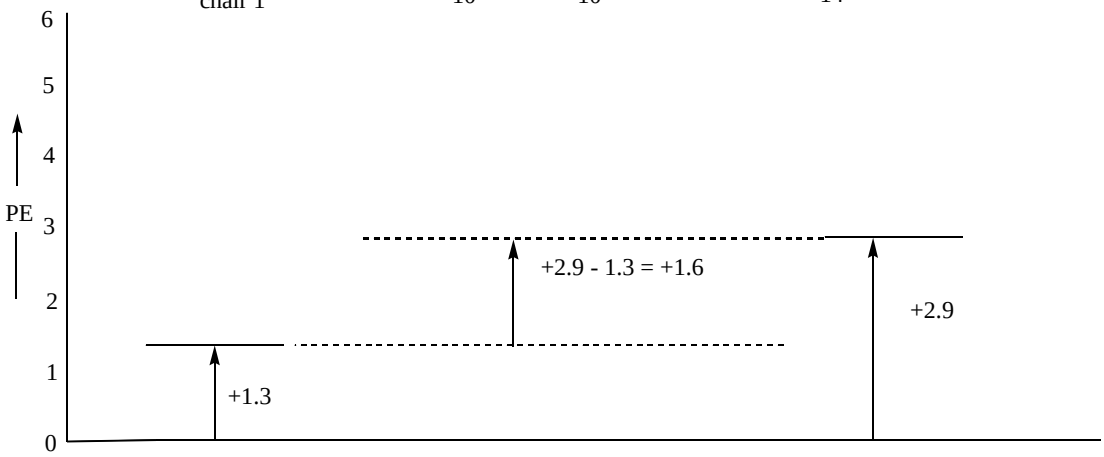
Newman projections:



axial Br = +0.5
gauche substituents = +0.8
total = 1.3

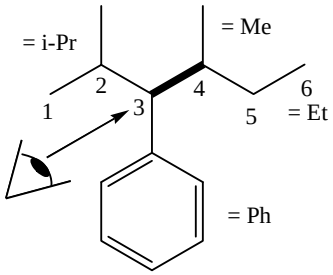
axial isopropyl = +2.1
gauche substituents = +0.8
total = 2.9

$$K = \frac{\text{chair 2}}{\text{chair 1}} = 10^{\frac{-\Delta G}{2.3RT}} = 10^{\frac{-1600}{1380}} = 10^{-1.16} = 0.069 = \frac{1}{14}$$



Energy changes of cis-1-bromo-2-isopropylcyclohexane conformations.

8. Use a Newman projection of the C3→C4 bond of 2,4-dimethyl-3-phenylhexane to **show the most stable conformation first**. Also show the highest energy conformation. Using the energy values provided in the table below, calculate the relative energies of the different conformations. Use this energy to calculate a ratio of these isomers. Plot the changes in energy in the graph diagram provided. Hint: First "bold" the bond viewed in your 2D structure and then decide your line of sight. On the final exam you will have to draw all 6 conformations. (20 pts)



2,4-dimethyl-3-phenylhexane

$\Delta G \approx \Delta H$

$K_{eq} = 10^{\frac{-\Delta H}{2.3RT}}$

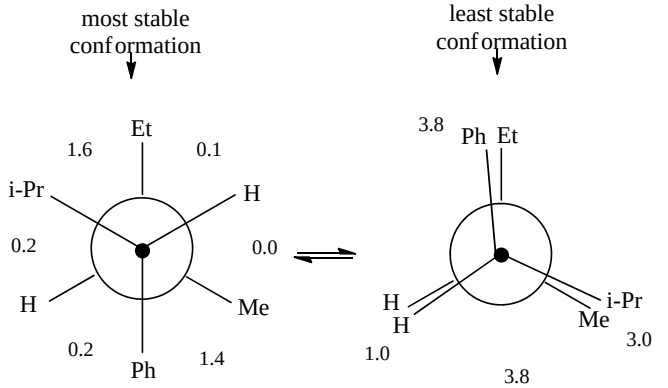
Approximate Eclipsing Energy Values (kcal/mole)

	H	Me	Et	i-Pr	t-Bu	Ph
H	1.0	1.4	1.5	1.6	3.0	1.7
Me	1.4	2.5	2.7	3.0	8.5	3.3
Et	1.5	2.7	3.3	4.5	10.0	3.8
i-Pr	1.6	3.0	4.5	7.8	13.0	8.1
t-Bu	3.0	8.5	10.0	13.0	23.0	13.5
Ph	1.7	3.3	3.8	8.1	13.5	8.3

Approximate Gauche Energy Values (kcal/mole)

	H	Me	Et	i-Pr	t-Bu	Ph
H	0	0	0.1	0.2	0.5	0.2
Me	0	0.8	0.9	1.1	2.7	1.4
Et	0.1	0.9	1.1	1.6	3.0	1.5
i-Pr	0.2	1.1	1.6	2.0	4.1	2.1
t-Bu	0.5	2.7	3.0	4.1	8.2	3.9
Ph	0.2	1.4	1.5	2.1	3.9	2.3

Because there are 2 chiral centers (my mistake) there are diastereomers, so there are 2 possible answers.

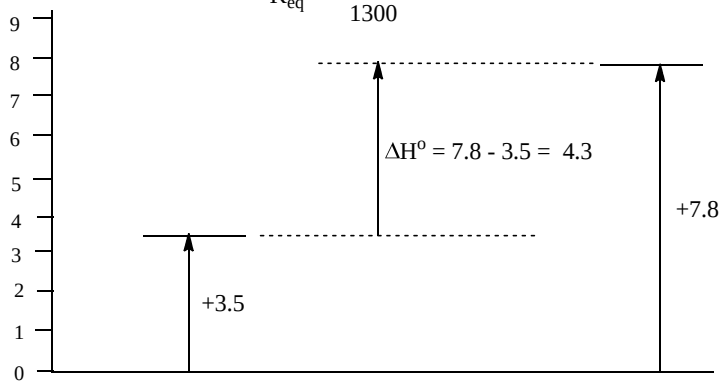


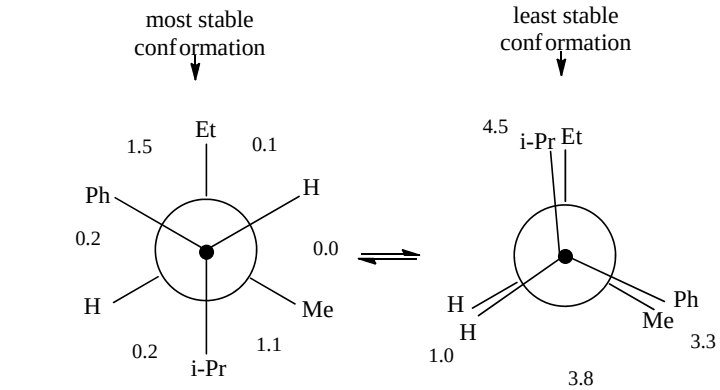
0.1 + 0.0 + 1.4 + 0.2 + 0.2 + 1.6 = $\Delta H^o = 3.5$

3.8 + 3.0 + 1.0 = $\Delta H^o = 7.8$

$K_{eq} = 10^{\frac{-\Delta H}{2.3RT}} = 10^{\frac{-(4300)}{1380}} = 10^{-3.12} = 0.00077$

$K_{eq} = \frac{1}{1300}$



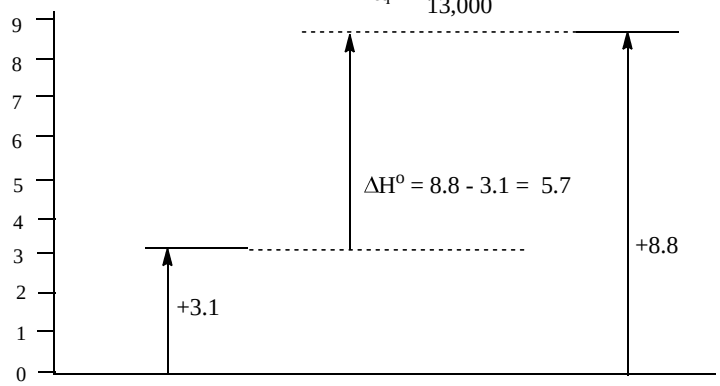


0.1 + 0.0 + 1.4 + 0.2 + 0.2 + 1.6 = $\Delta H^o = 3.1$

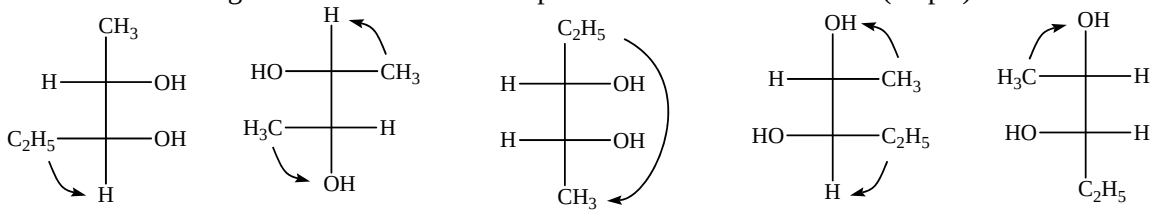
3.8 + 1.4 + 1.6 = $\Delta H^o = 8.8$

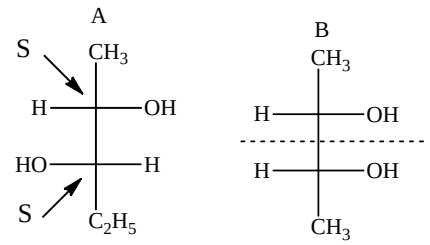
$K_{eq} = 10^{\frac{-\Delta H}{2.3RT}} = 10^{\frac{-(5700)}{1380}} = 10^{-4.13} = 0.000074$

$K_{eq} = \frac{1}{13{,}000}$



9. For the following set of Fischer projections answer each of the questions below by circling the appropriate letter(s) or letter combination(s). Hint: Redraw the Fischer projections with the longest carbon chain in the vertical direction and having similar atoms in the top and bottom portion. Classify all chiral centers in the first structure as R or S absolute configuration and write an acceptable name for that isomer. (30 pts)





a. Which are optically active? A B C D E

b. Which are meso? A B C D E

c. Which is not an isomer with the others? A B C D E — B is not an isomer with any of the others.

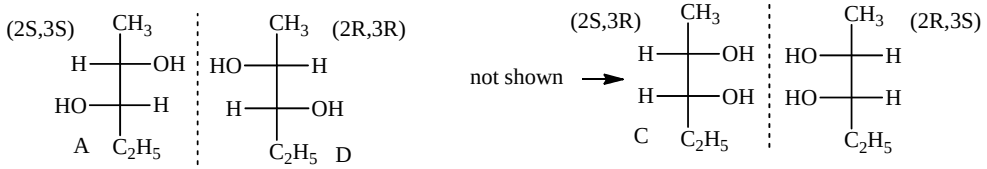
d. Which pairs are enantiomers? ~~AB~~ AC ~~AD~~ AE ~~BC~~ ~~BD~~ ~~BE~~ CD CE DE

e. Which pairs are identical? AB AC AD AE BC BD BE CD CE DE

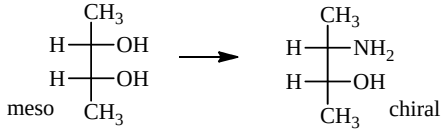
f. Which pairs are diastereomers? AB AC AD AE BC BD BE CD CE DE

g. Which pairs, when mixed in equal amounts will not rotate plane polarized light? AB AC AD AE BC BD BE CD CE DE — Enantiomers cancel each others rotations.

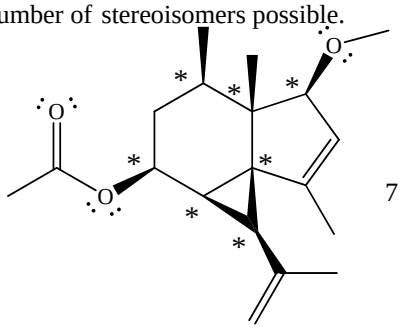
h. Draw any stereoisomers of pentane-2,3-diol as Fischer projections, which are not shown above. If there are none, indicate this.



i. Would anything change if, in compound B, an OH was replaced with an NH_2 group?



j. The structure of Shagene A is shown below. It is one of two related compounds recently isolated from choral (Org. Lett., ASAP, April 29, 2014). Circle all stereogenic centers in following molecule and calculate the maximum number of stereoisomers possible.



7 chiral centers

maximum number of stereoisomers = $2^7 = 128$

Humans are not prisoners of fate, but only prisoners of their own minds. - Franklin D. Roosevelt