



Concordia
UNIVERSITY

F05 Rogers

COURSE	ORGANIC CHEMISTRY I	NUMBER	CHEM 221	SECTION	/2-01
EXAMINATION	Final Examination	DATE	December 20, 2005	TIME	1400-1700
INSTRUCTOR	Dr. Carrie ROGERS				

MATERIALS ALLOWED: NO YES (PLEASE SPECIFY) molecular model kits (without instructions)

CALCULATORS ALLOWED: NO YES programmable calculators must be "reset"

Chem 221 --- ORGANIC CHEMISTRY I

LAST NAME: marking scheme FIRST NAME: _____
STUDENT NUMBER: _____ SIGNATURE: _____

Instructions: PLEASE READ THIS PAGE WHILE WAITING TO START!

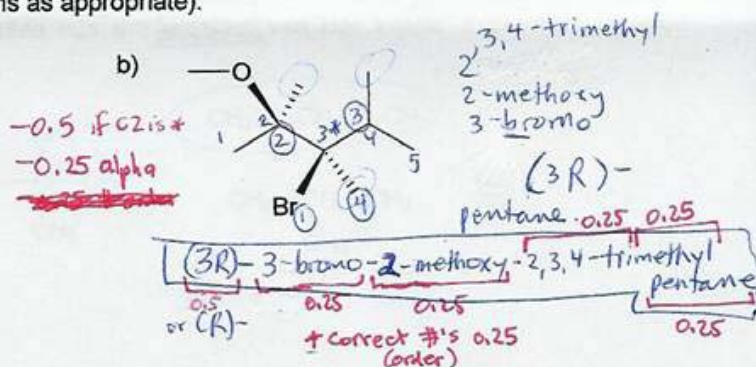
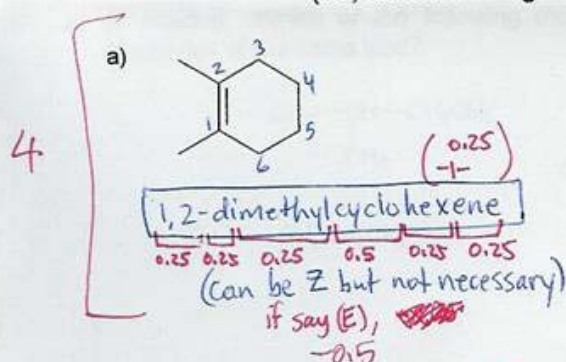
- Make sure your exam has 14 pages, including this cover page & a periodic table.
- You may detach page containing the periodic table and pK_a data.
- Write your student ID number on all pages.
- Write all answers legibly in the space provided (use the backs of pages for rough work).
- Non-programmable calculators are allowed; cell phones & electronic dictionaries are not.
- Suggestion: if spend 15 min / page (except bonus) \Rightarrow 30 min. extra to check your work.

NOTE: the headers on the rest of the pages say Winter 2005, but this really is the F2005 exam.

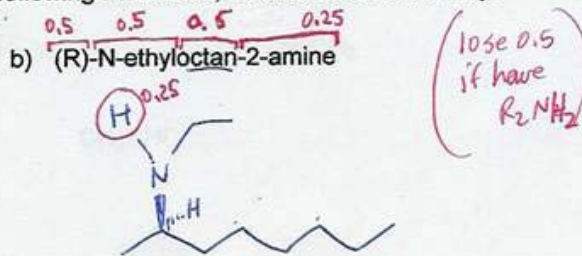
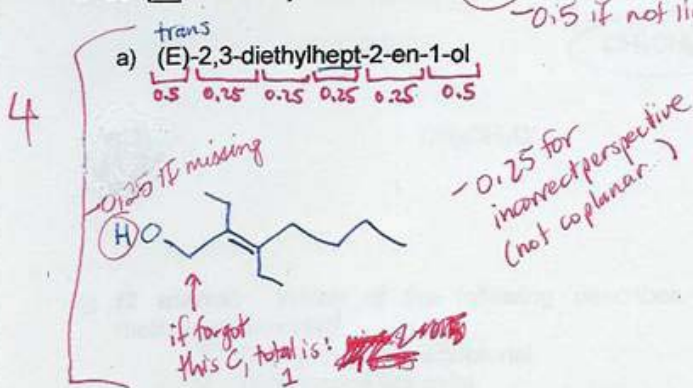
1. (/ 10 marks) Circle the word(s) that correctly completes each of the following statements:

- a) Electrophiles are strongly attracted to the π -electrons in alkenes and alkynes because π -electrons are relatively far from their atoms' nuclei and have high (~~ELECTRON DENSITY~~ / POLARIZABILITY).
- b) To help favour elimination over substitution, chemists often (INCREASE / DECREASE) the reaction temperature, because elimination is a highly entropically favoured process whereas substitution is not.
- c) Simultaneous constructive and destructive interference of two atomic orbitals leads to the formation of one bonding molecular orbital and one (~~NONBONDING~~ / ANTIBONDING) molecular orbital.
- d) The (POSITIVE FORMAL CHARGE / OPEN VALENCE) at the carbocationic center is what causes carbocations to be unstable, reactive intermediates.
- e) According to the Cahn-Ingold-Prelog rules for assigning priorities, higher priority is given to the substituent whose connecting atom has the larger (ELECTRONEGATIVITY / ATOMIC MASS).
- f) S_N1 reactions typically follow a (ONE STEP / TWO-OR-MORE STEP) mechanism.
- g) A molecule is most likely to collide with the (~~LEAST STABLE~~ / MOST STABLE) conformation of another molecule if the two compounds are in the same solution.
- h) Cis and trans isomers of alkenes are examples of (STEREISOIMERS / CONFORMERS).
- i) The transition state of bimolecular elimination reaction resembles a(n) (CARBOCATION / ALKENE).
- j) Radical intermediates (CAN / CANNOT) stabilize themselves by undergoing rearrangements.

2. (/ 4 marks) Name the following molecules according to IUPAC conventions; include stereochemistry (i.e., absolute configurations as appropriate).



3. (/ 4 marks) Draw skeletal (line) structures of the following molecules; include stereochemistry.



4. (/ 4 marks) Provide an example of each of the following types of species (i.e., draw their structures).

NO PART MARKS

a) a pair of enantiomers

any

bad perspective
 -0.25

no stereo ⇒ no marks!

b) a protic solvent

any alcohol
 H₂O
 amine

H₂SO₄ (e) gets 0.5 marks
 any weak acids get 0.5

c) a base useful for deprotonating ammonia

RNH[⊖]
 CH₂=CH[⊖]
 CH₃[⊖]
 CH₃CH₂CH₂CH₂[⊖]
 etc

no marks if show conjugate acid form.

(pK_a of HA > 36)

0.5 for [⊖]NH₂

lose 0.25 if draw covalent bond b/w ⊖+⊕

d) a molecule with significant angle strain

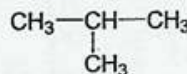
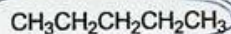
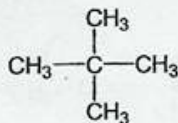
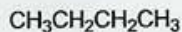
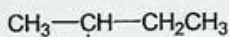


↪ = ring strain, not torsional strain

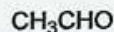
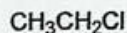
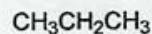
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5. (8 marks) MULTIPLE CHOICE: Circle the correct choice.

- a) (2 marks) Which of the following molecules has the greatest van der Waals' interaction between molecules of the same kind?



- b) (2 marks) Which of the following substances would have the highest solubility in water?



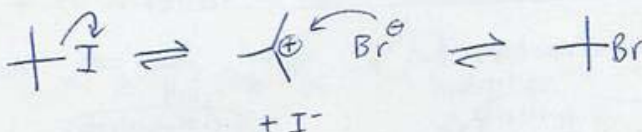
- c) (2 marks) Which of the following describes the most stable conformation of *cis*-1-*tert*-butyl-3-methylcyclohexane?

1. Both groups are equatorial.
2. Both groups are axial.
3. The *tert*-butyl group is equatorial.
4. The *tert*-butyl group is axial.
5. none of the above



- d) (2 marks) The S_N1 reaction between *tert*-butyl iodide and NaBr would be faster in acetone ($\epsilon = 21$) than in THF ($\epsilon = 7.6$) because:

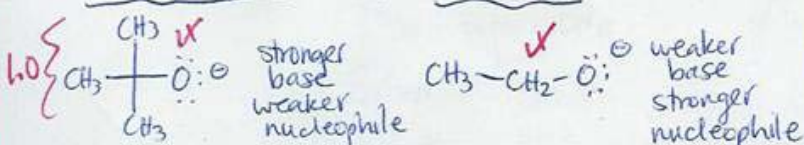
- less polar
1. ~~the transition state of the rate limiting step has lower charge density than the reactants, so is stabilized more by a more polar solvent.~~
 2. the transition state of the rate limiting step has higher charge density than the reactants, so is stabilized more by a more polar solvent. ✓
 3. ~~the transition state of the rate limiting step has lower charge density than the reactants, so is stabilized more by a less polar solvent.~~
 4. the transition state of the rate limiting step has higher charge density than the reactants, so is stabilized more by a less polar solvent.
 5. none of the above.
- more polar



6. (/ 12 marks) For these questions, include drawings to support your explanations.

a) (6 marks) Tert-butoxide is a stronger base but a weaker nucleophile than ethoxide. Explain what causes each of these phenomena.

t-butoxide vs. ethoxide

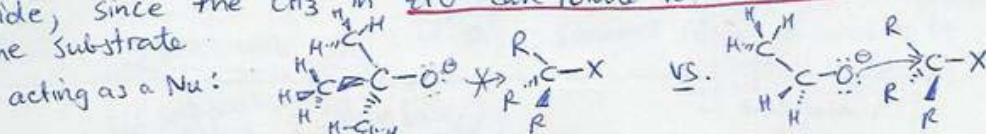


① STRONGER BASE: more reactive lone pair \rightarrow in defn

1.5 { \checkmark more electron-donating groups attached to the α -carbon (inductive electron donation)
 \checkmark 3 CH_3 's vs. 1 CH_3 in ethoxide
 \checkmark causes lone pair on O to be more e⁻ rich / more reactive
 \therefore held less tightly to the O nucleus \rightarrow more reactive

2.0 { Definitions }
 (A) Basicity: due to electron-richness & exposure of lone pair on oxygen (more basic if held less tightly to atom)
 (B) Nucleophilicity: due to ability of base to attack sterically hindered sites
 \checkmark (less nucleophilic if base is sterically bulky itself)
 \checkmark attack δ^+ C + other non-H atoms

② WEAKER NUCLEOPHILE: less able to access δ^+ C's \rightarrow via backside attack
 - extra methyl groups on $^t\text{BuO}^-$ make the molecule considerably larger than ethoxide, since the CH_3 's in $^t\text{BuO}^-$ can rotate to avoid steric hindrance



b) (6 marks) "Markovnikov and anti-Markovnikov additions actually follow the same rules". To what is this statement referring, and why is it a helpful way to think? In electrophilic additions \rightarrow (more able if other atoms com, etc.)

2.5 { "The same rules" = electrophile always adds to the least substituted sp^2 C in the alkene, since this C is the more e⁻ rich
 + define Mark/anti (or show it somehow)
 where applicable \rightarrow leaving the more highly substituted (more e⁻ rich) sp^2 C to bear the positive charge / open valance in the carbocationic intermediate... Nu adds to this C.

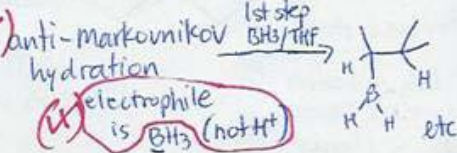
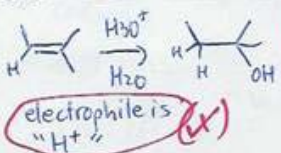
Why is it helpful? PREDICTING ELECTROPHILIC ADDITION PRODUCTS

flexible... 1.5 { - no need to memorize outcome of every specific set of conditions
 - simply need to learn to identify electrophile + nucleophile + most electron-rich sp^2 C in alkene

- allows us to predict regiochemistry of electrophilic additions easily

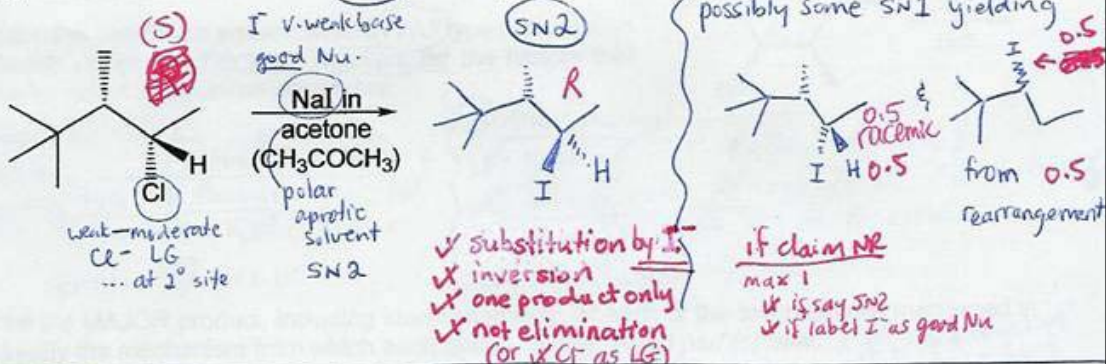
Supporting examples: to show difference b/w markov. + antimarkovnikov.

Markovnikov hydration (H's go where H's are)

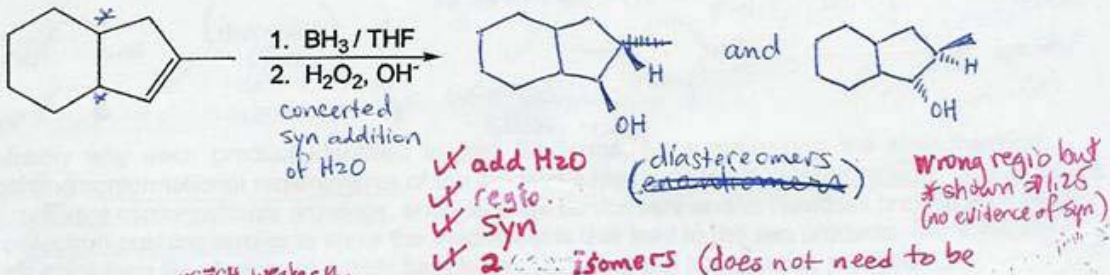


7. (/ 8 marks) REACTIONS: Predict the major product(s) for each reaction; include stereochemistry.

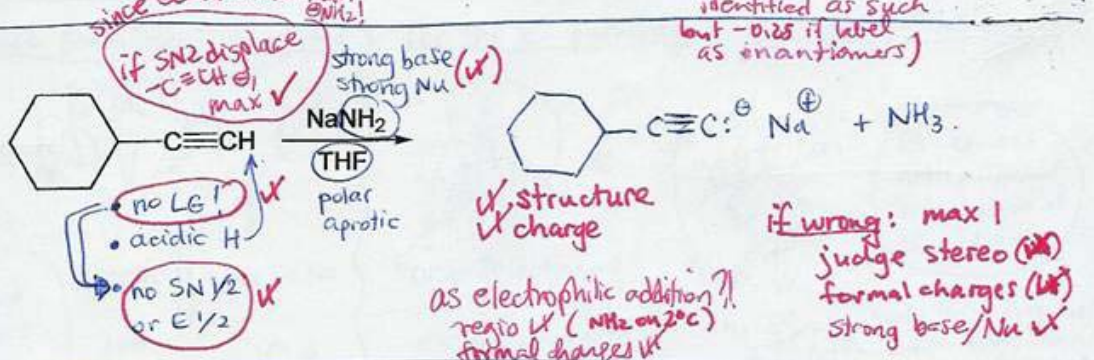
a) (2 marks)



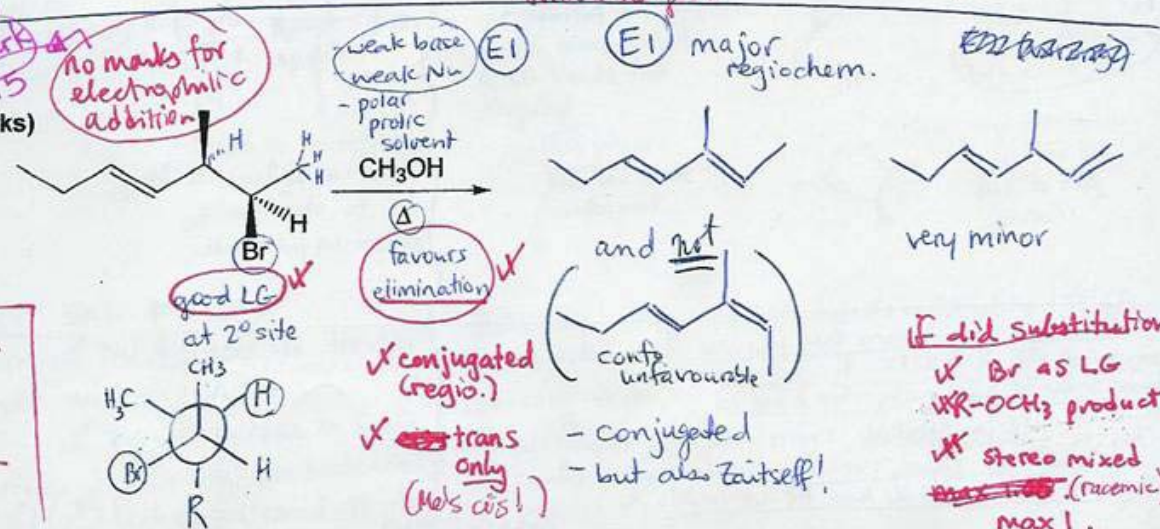
b) (2 marks)



c) (2 marks)

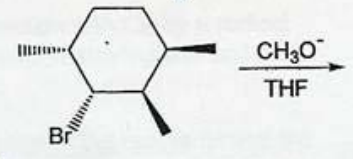


d) (2 marks)



$\checkmark = 0.25$ $\times = 0.5$ $\checkmark = 1.0$

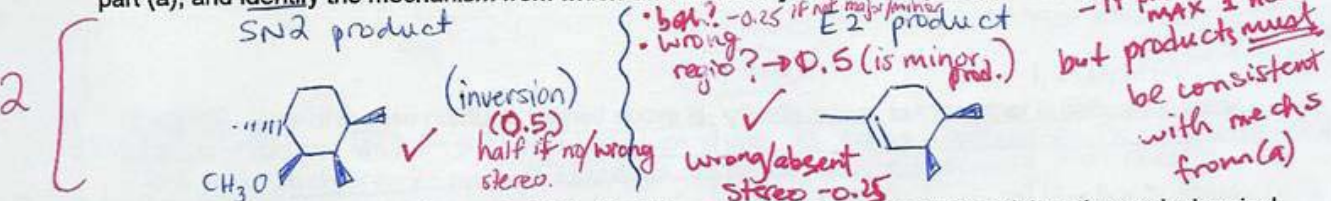
8. (/ 11 marks) Consider the following reaction mixture:



a) (3 marks) Under the conditions shown, which TWO types of reaction could this molecule undergo? [For each reaction, list the factors that allow you to predict which mechanism dominates.]

- 3
- ① Substitution \checkmark
 - good LG, $2^\circ \Rightarrow$ either $\text{S}_\text{N}1$ or $\text{S}_\text{N}2$
 - Strong Nu \Rightarrow favours $\text{S}_\text{N}2$
 - polar solvent \Rightarrow ok for either
 - concl. \Rightarrow $\text{S}_\text{N}2$
 - ② Elimination \checkmark
 - good LG, $2^\circ \Rightarrow$ either $\text{E}1$ or $\text{E}2$
 - strong base \Rightarrow favours $\text{E}2$
 - polar solvent \Rightarrow ok for either
 - conclusion \Rightarrow $\text{E}2$
- if only this: \checkmark*

b) (2 marks) Draw the MAJOR product, including stereochemistry, of each of the two reactions mentioned in part (a), and identify the mechanism from which each arises. [Note: Read part (c) now...]



c) (6 marks) Justify why each product identified in part (b) forms, by summarizing the regiochemical, stereochemical and conformational requirements of the reaction's mechanism. You must include:

- relevant conformational drawings, such as chair conformers and/or Newman projections
- electron-pushing arrows to show the mechanisms that lead to the two products (no \neq needed)
- a point-form list of relevant details beside each drawing (no paragraphs, please!)

6

For the $\text{S}_\text{N}2$ pathway: concerted

the backside of the C-Br bond (ie: the σ^* orbital) is accessible in both conformations!

CONFO

OCH_3^- acting as Nu

STEREO leads to inversion of configuration at the site of attack by nucleophile

For the $\text{E}2$ pathway: also concerted

OCH_3^- acting as base

CONFO

E2 requires anti-periplanar orientation of LG and β -H

only this conformer (more stable) can lead to $\text{E}2$ \therefore has $\beta\text{H} + \text{LG}$ trans & both axial.

NR from the less stable conformer.

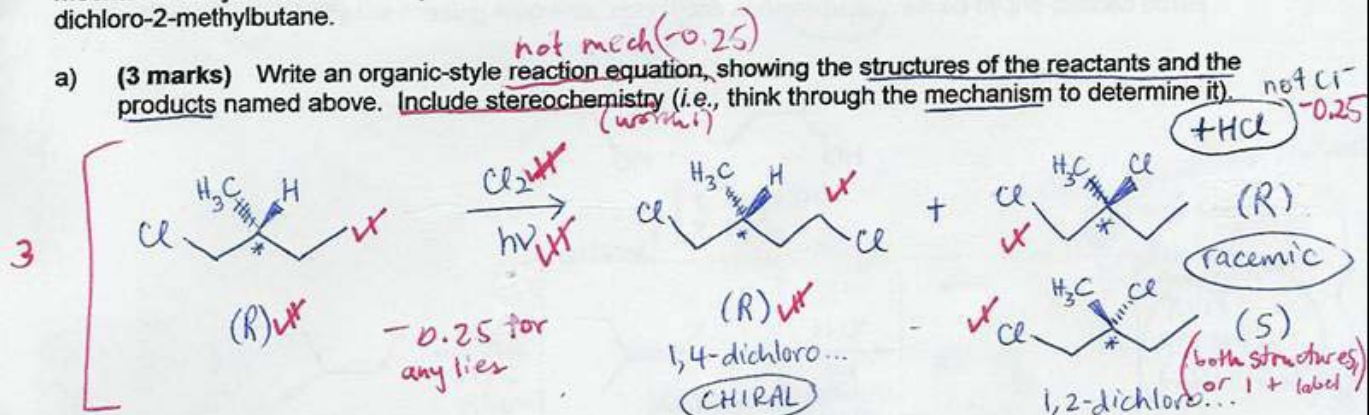
must be cis due to ring (stereo)

- Summary: $\text{S}_\text{N}2 \neq$ worth \checkmark
- regiochem. \checkmark Nu displaces LG directly \therefore most of c!!!
 - stereochem. \checkmark inversion
 - confo. \checkmark require access to C-LG σ^* orbital (backside attack)
- both confos can do it - but easier if LG axial

- Summary: $\text{E}2$
- regiochem. \checkmark usually get more highly substituted alkene if >1 βH is able to become aligned anti-periplanar to LG-C bond
 - stereochem. \checkmark cis/trans dictated by confo. + ring.
 - confo. \checkmark as above, anti-periplanar βH -LG. requires βH and LG both axial, + trans
- ok if just say this, since 1 axial confo.*

9. (1/9 Marks) (R)-1-chloro-2-methylbutane undergoes light-induced reaction with Cl₂ by a radical mechanism to yield a mixture of products. Among the products are 1,4-dichloro-2-methylbutane and 1,2-dichloro-2-methylbutane.

a) (3 marks) Write an organic-style reaction equation, showing the structures of the reactants and the products named above. Include stereochemistry (i.e., think through the mechanism to determine it).



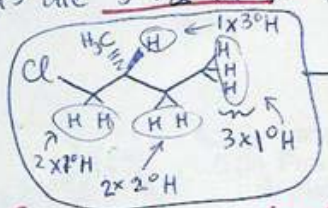
b) (2 marks) One of the two products named above is optically active, but the other is optically inactive. Which is which, and why?

2

The 1,4-dichloro-2-methylbutane is optically active because the reaction did not change involve making or breaking a bond to the chiral centre; thus, it is still enantiomerically pure + will have measurable optical rotation.
The 1,2-dichloro-2-methylbutane is optically INACTIVE because the reaction involved abstracting the H from the chiral centre, leaving a planar radical that Cl• could attack from either face. Thus, this compound is RACEMIC + has zero net optical rotation.

c) (4 marks) Are the products shown in part (a) likely to be the major products of this reaction? If so, explain why, based on your understanding of the mechanism of the reaction. If not, briefly explain why not, and draw the structure(s) of the predicted major product(s).

Radical chlorination proceeds via Cl• attacking + abstracting an H atom. Cl•s are very reactive and not very selective but still the most easily abstracted H's are 3° > 2° > 1°. However, the more H's there are, the more likely that type of H will encounter a Cl• atom and be abstracted.



Specific discussion of stats. vs. 1°/2°/3° ease of abstraction other products also are likely:

1,4-dichloro... involved abstraction of 1° H (1 of 3...)
Likely minor product
 $\frac{3 \times 1.0}{17.6} \approx 17\%$ of yield

1,2-dichloro... involved abstraction of (3° H) (1 of 1...)
Likely majorish product
 $\frac{1 \times 5.0}{17.6} \approx 28\%$ of yield

1,1-dichloro... involving abstraction of more reactive 1° H (1 of 2...)
 $\frac{2 \times 1.0}{17.6} \approx 11\%$ of yield

1,3-dichloro... involving abstraction of 2° H (1 of 2)
racemic
 $\frac{2 \times 3.8}{17.6} \approx 43\%$ of yield
= most likely product

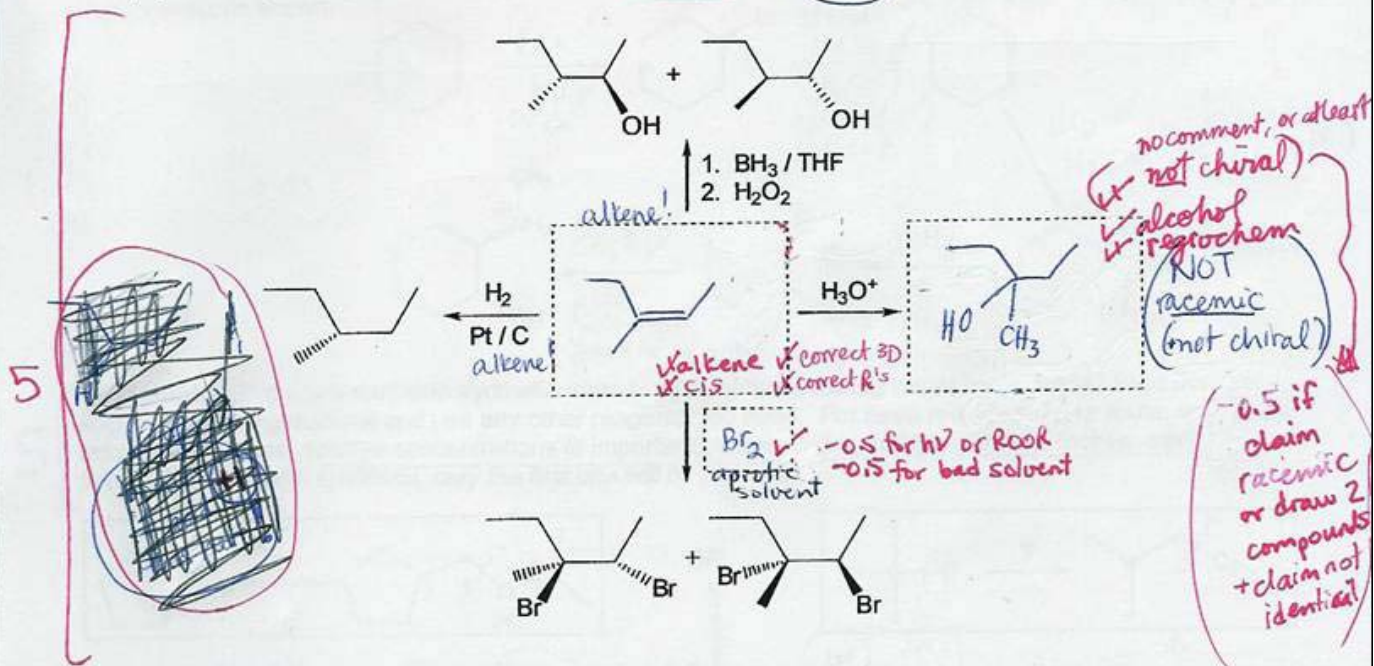
Thus, because of the high reactivity of the small Cl• radicals, they are not very selective + yield mixtures of products during chlorination reactions. The dominant product in this case is likely the 1,3-dichloro racemate.

9

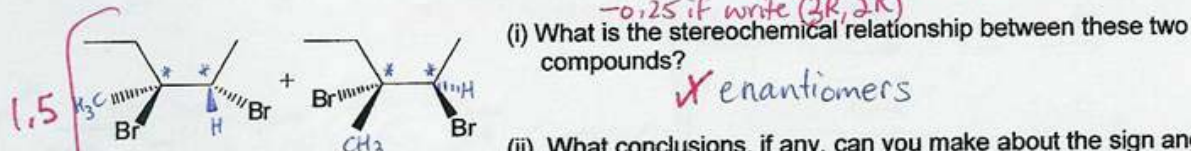
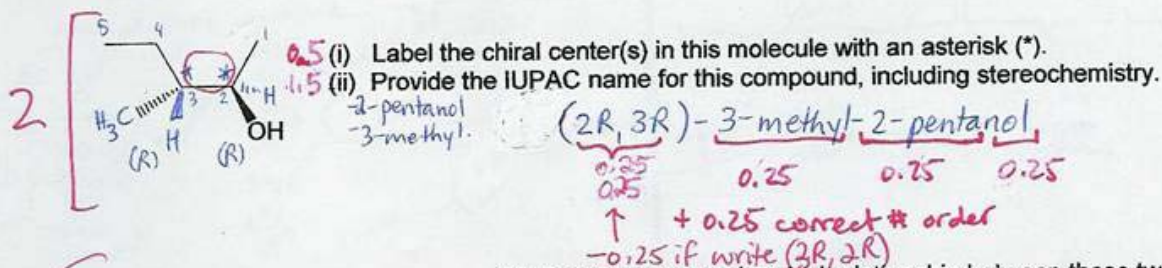
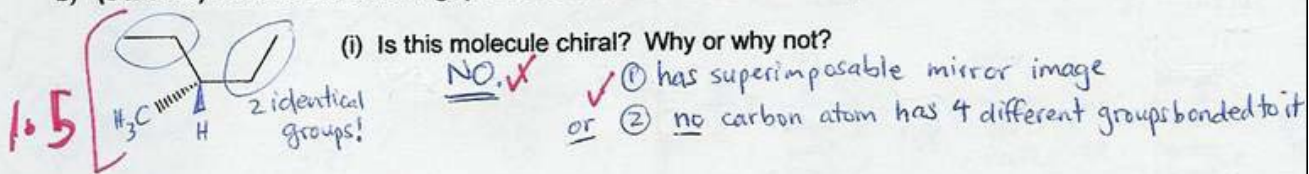
if claim dominant is the 3° site, then only -0.5 for not drawing other

10. (/ 10 marks) REACTIONS and STEREOCHEMISTRY:

a) (5 marks) Identify the missing reactants, conditions and products marked by the dashed boxes.



b) (5 marks) Answer the following questions about the stereochemistry of the compounds from part (a).



(ii) What conclusions, if any, can you make about the sign and/or magnitude of the specific rotation of these two compounds?

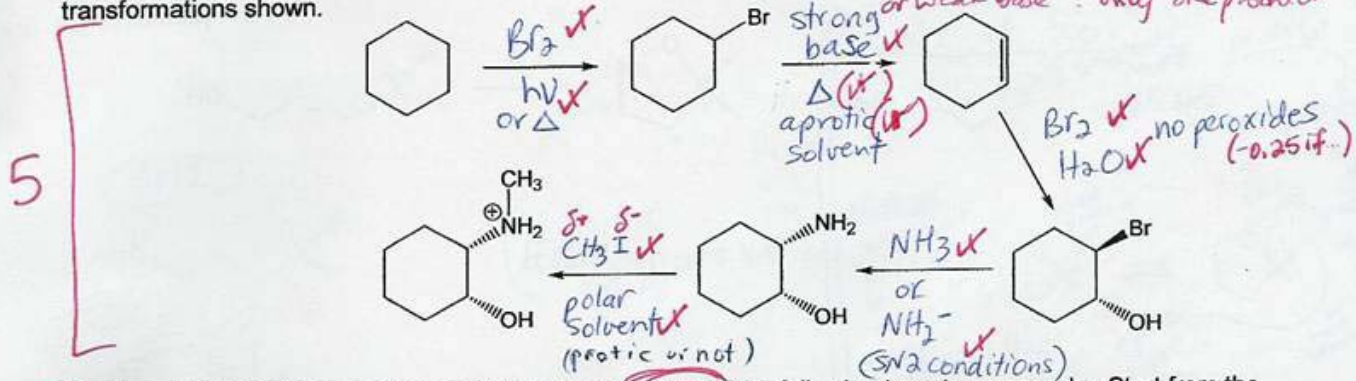
Handwritten notes:

- "magnitude: same but otherwise unknown" written in red.
- "sign: opposite" written in red.
- "if chiral diastereomers: can make not conclusions" written in red.
- "if misinterpret as mixed (-.0° rotation) give it" written in red.
- "must be consistent with label in (a)" written in red.

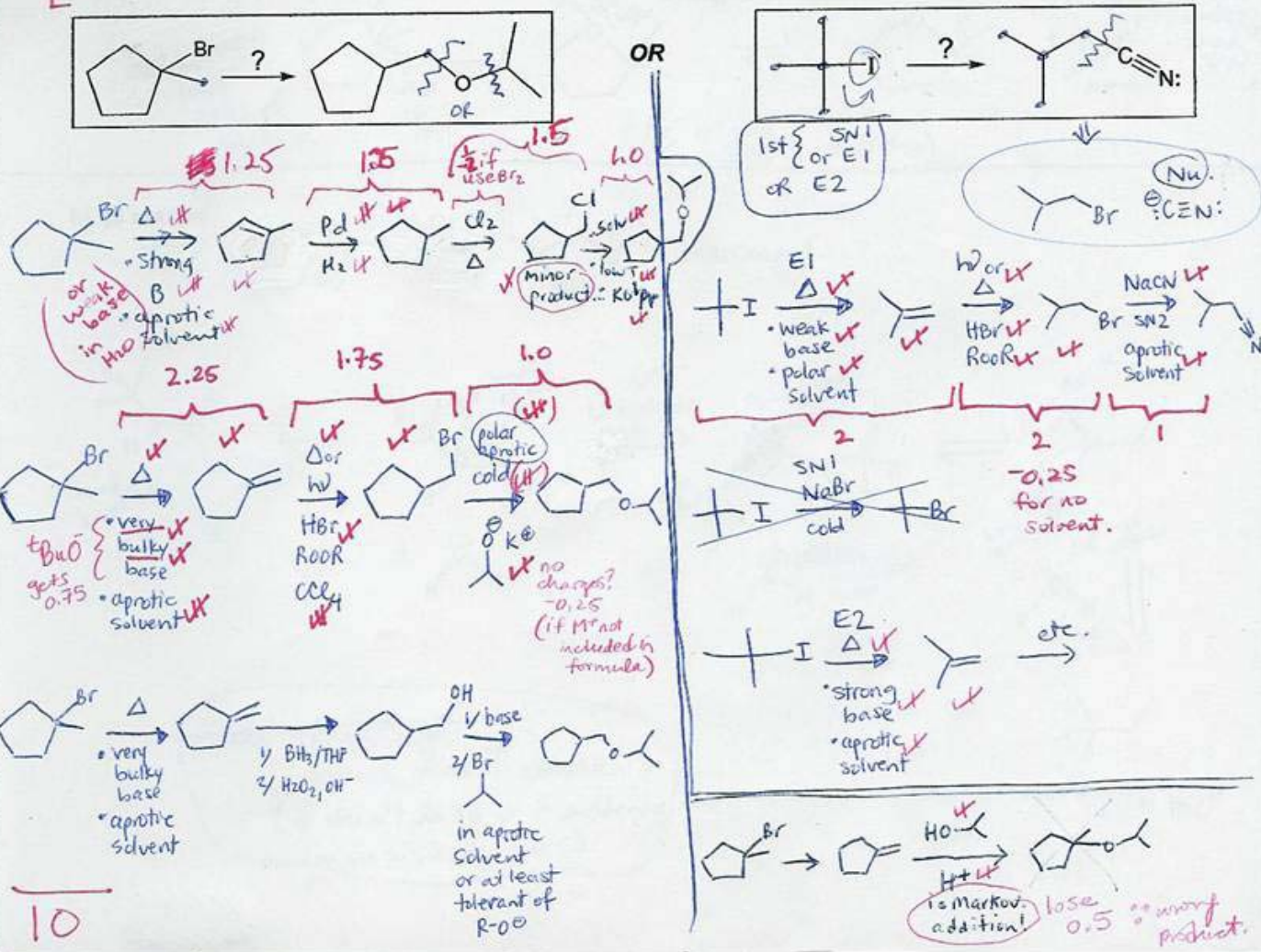
10

11. (/ 10 marks) SYNTHESIS OF TARGET COMPOUNDS

a) (5 marks) Above the arrow for each reaction, identify the reagents and conditions required to achieve the transformations shown.

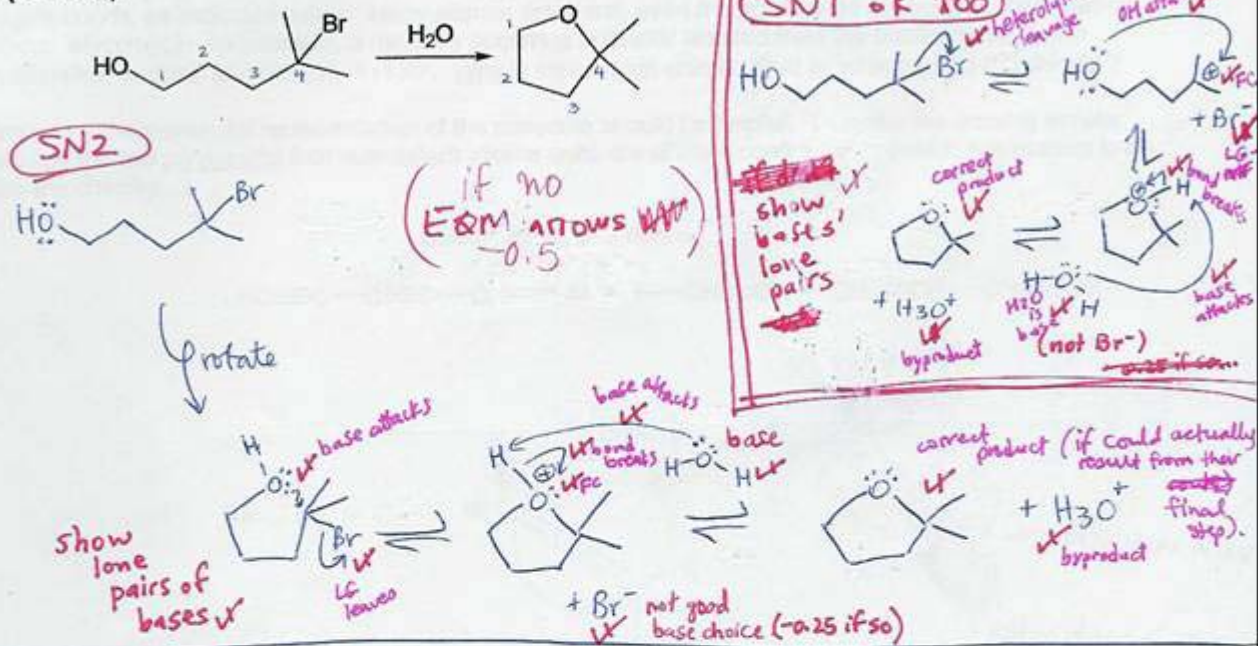


b) (5 marks) Provide a multistep synthetic route to ONE of the following target compounds. Start from the suggested starting material and use any other reagents you need. For each reaction in your route, specify the reaction conditions: relative concentrations (if important), solvent type, and temperature (hot vs. cold). [Note: If you do both synthesis, only the first one will be marked.]

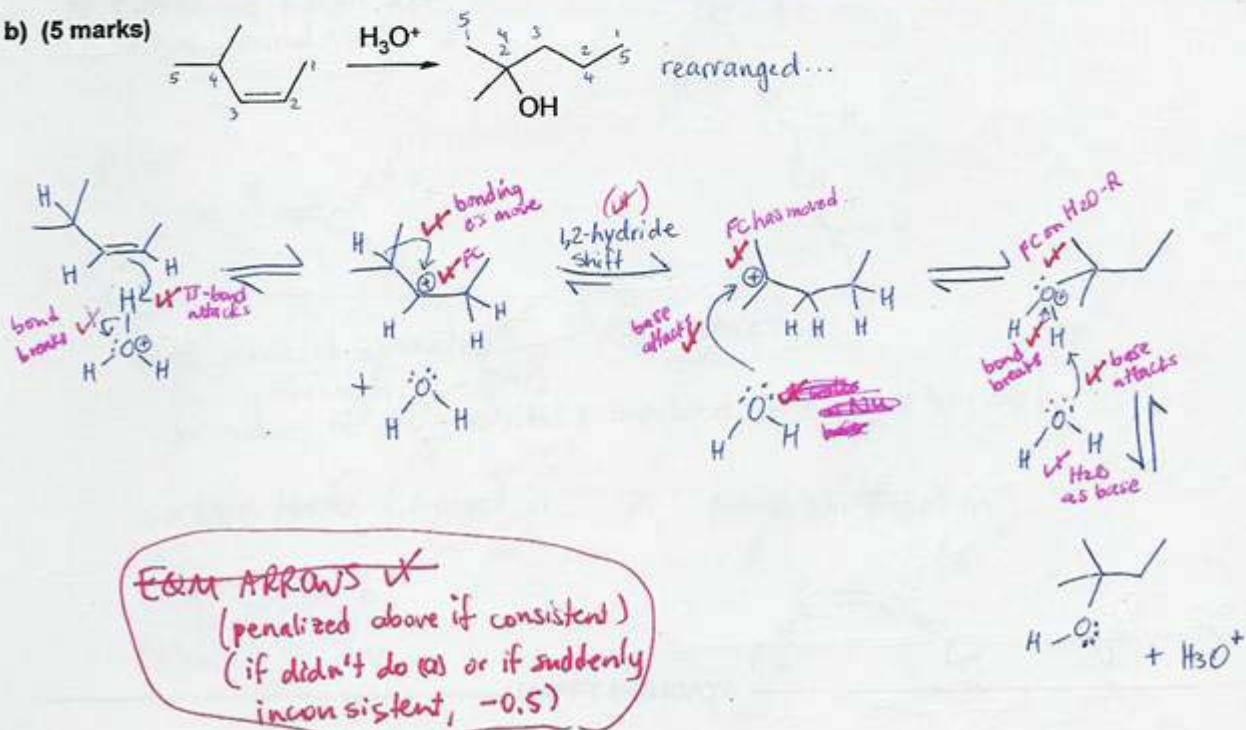


12. (/ 10 marks) **MECHANISMS:** Write complete step-by-step "arrow-pushing" mechanisms to explain how the products shown would be formed.

a) (5 marks)



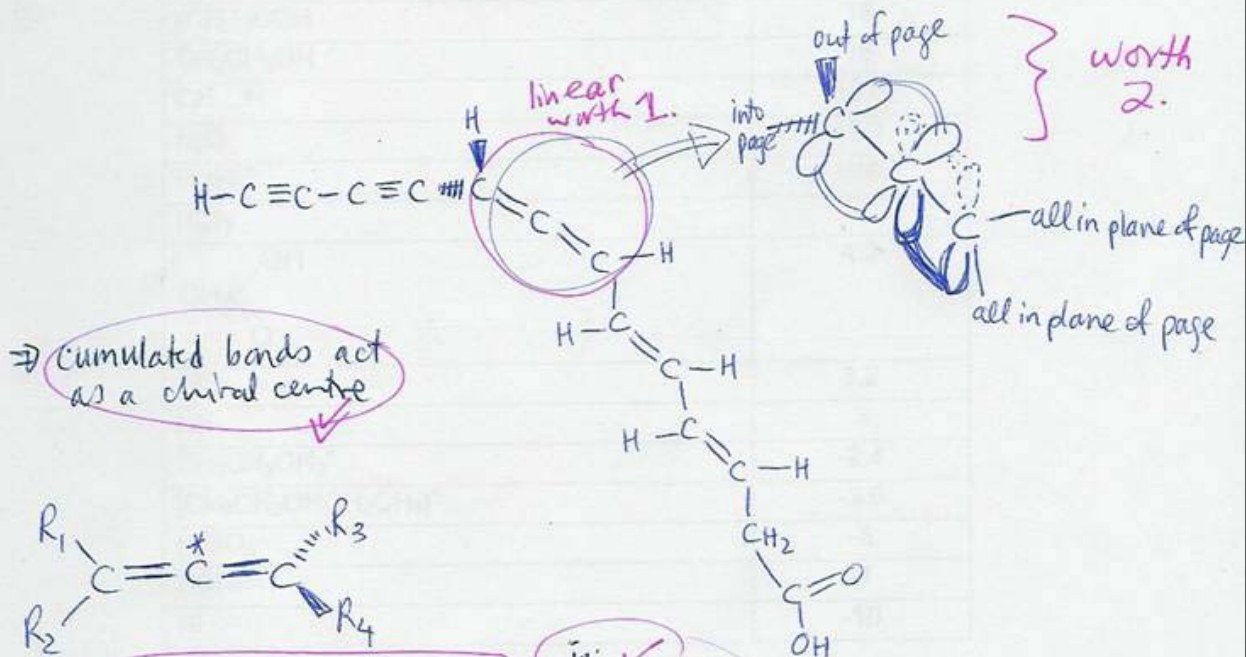
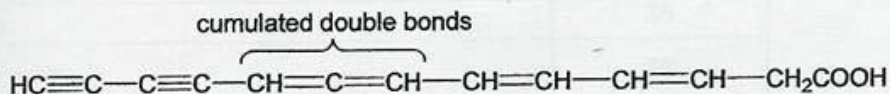
b) (5 marks)



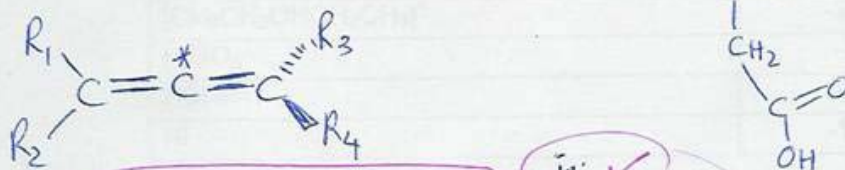
BONUS QUESTION: (/ 5 marks)

Allenes are a special class of alkenes that contain adjacent carbon-carbon double bonds, known as cumulated double bonds, as indicated below. Many allenes are chiral, even though they do not contain chiral carbon atoms. Mycomycin, for example, a naturally occurring antibiotic isolated from the bacterium *Nocardia acidophilus*, is chiral and has $[\alpha]_D = -130^\circ$. Why is mycomycin chiral? That is, what causes the chirality?

Drawing a 3-dimensional representation of the molecule should be helpful. To make the drawing simpler, assume the two conjugated (not cumulated) alkene units are of *trans* configuration (which has nothing to do with the chirality...).



⇒ cumulated bonds act as a chiral centre



⊗ no plane of symmetry (ie: asymmetric) slicing through C-C-C because of *'s orbitals involved in the 2π bonds...

