NAME _____

ID # _____

ORGANIC CHEMISTRY I (CHEM 2301)

9:30 – 10:20 am, July 16, 2013

Exam 2

If you want to pick your graded exam up tomorrow in class (in public), please check the box on the right: ☐

If you do not check the box, I will not bring your exam to class on Wednesday, and you will need to pick up your exam in private from Chemistry department staff in 115 Smith beginning Thursday, July 18th. Exams that are not picked up within two weeks will be disposed of.

A periodic table is attached to the back of this exam as an aid. Otherwise, you are not permitted to use any other materials (including notes, books, or electronic devices of any kind).

Right now, write your name and student ID number at the top of this page. When the exam begins, please write your name at the top of the next page.

You may use pen or pencil. However, re-grades will be considered only for exams completed in pen.

Please write your answers in the boxes/spaces provided. If your answer is not in the appropriate space (say, for example, it's on the back of the page), draw us an arrow and/or note telling us where to look.

NAME _____

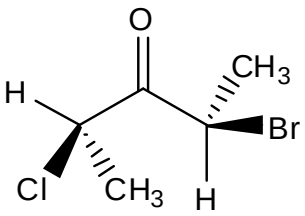
Scoring: 1. _____ / 12 4. _____ / 22

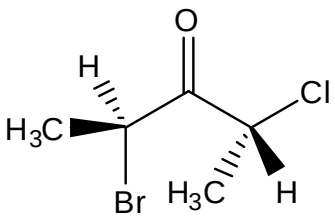
2. _____ / 20 5. _____ / 31

3. _____ / 15

Total Score: _____ / 100

1. (12 pts) How would you describe the relationship between each of the pairs of structures below? Are they enantiomers or diastereomers, or are they just two ways of illustrating the same molecule? **Circle one answer** for each pair**.**





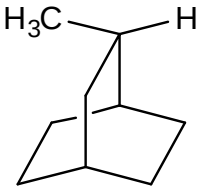
ENANTIOMERS

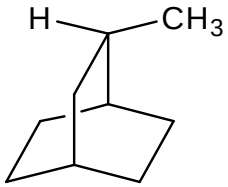
or

DIASTEREOMERS

or

SAME MOLECULE





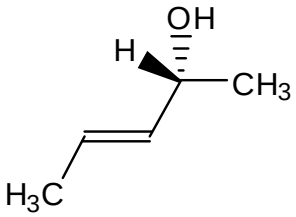
ENANTIOMERS

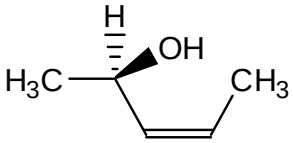
or

DIASTEREOMERS

or

SAME MOLECULE





ENANTIOMERS

or

DIASTEREOMERS

or

SAME MOLECULE

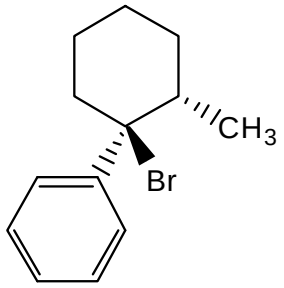
2. (20 pts) The starting material below can react with sodium methoxide ($NaOCH_3$, a source of $^{\ominus}OCH_3$) by all four mechanisms we covered recently—S_N2, S_N1, E2, and E1. Draw the predominant product that would be formed by each mechanism. Illustrate stereochemistry in your answer where appropriate. If a reaction generates a perfectly racemic mixture of enantiomers, draw just one enantiomer in the box, , and include the note "+ enantiomer".

S_N2 product

S_N1 product

$^{\ominus}OCH_3$, by **S_N2**

$^{\ominus}OCH_3$, by **S_N1**



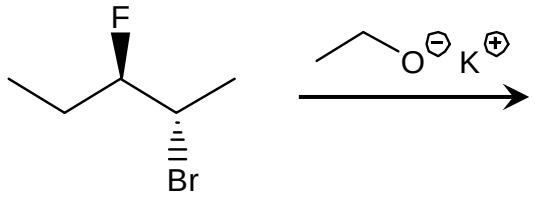
$^{\ominus}OCH_3$, by **E2**

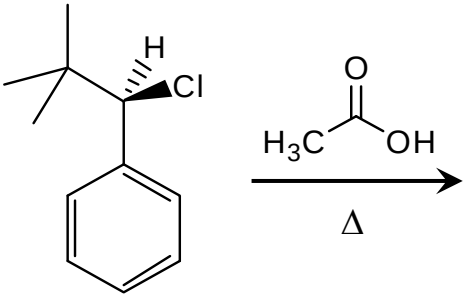
$^{\ominus}OCH_3$, by **E1**

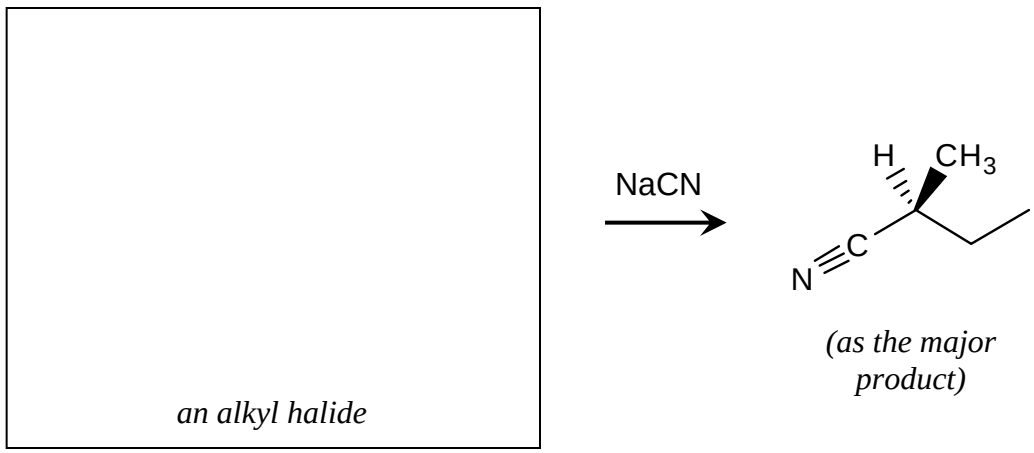
E2 product

E1 product

3. (15 pts) Draw the missing reactant or product in the empty boxes. For products, give the predominant, most favored product. Illustrate stereochemistry in your answer where appropriate. For reactions that yield multiple enantiomers, draw only one enantiomer in the box, and include the note "+ enantiomer".



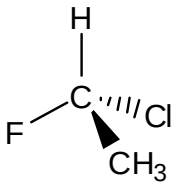


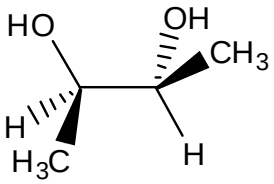


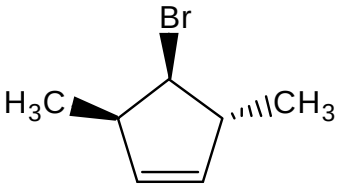
an alkyl halide

(as the major product)

4. (22 pts) On the structures below, **label each chiral center** with its appropriate Cahn-Ingold-Prelog designation [(*R*) or (*S*)]. Make it clear which atom in the drawing you are labeling. Then, for each structure, **circle** whether you think the molecule is chiral or achiral.





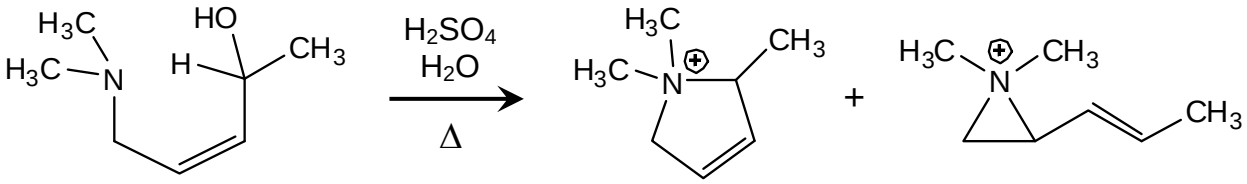


CHIRAL *or* **ACHIRAL** ?

CHIRAL *or* **ACHIRAL** ?

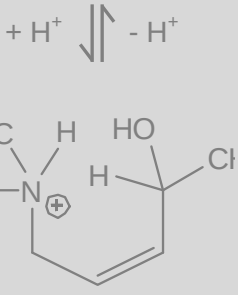
CHIRAL *or* **ACHIRAL** ?

5. (31 pts) The starting material shown below can interact with an acid (like H_2SO_4) in two ways: (i) it can be reversibly protonated at nitrogen, which we will ignore in this problem; or (ii) it can react to form products **A** and **B**. These two products differ in both alkene stability (which typically vary by 0-5 kcal/mol) and ring strain (which can be worth as much as 30 kcal/mol).



product **A**

product **B**



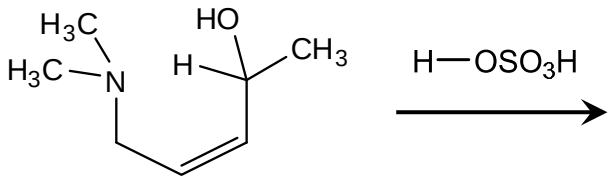
ignore this process for this problem

(a) Which of the two products above will be favored over the other? **Circle the favored product.**

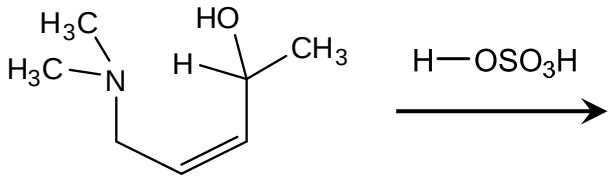
(b) Draw mechanisms that explain how products **A** and **B** are formed from starting material. ***Each mechanism should be three steps long***. In each answer, make sure that you:

- Draw each step of the mechanism separately.
- Use "electron pushing" to show where the electrons in each step go.
- Use only the molecules that you are given; do not invoke reactants or solvents that aren't in the problem.
- The first step of each mechanism is a proton transfer. I have drawn the reactants for you, but you will still need to add curved arrows to "push electrons" in that step.

mechanism for product **A**

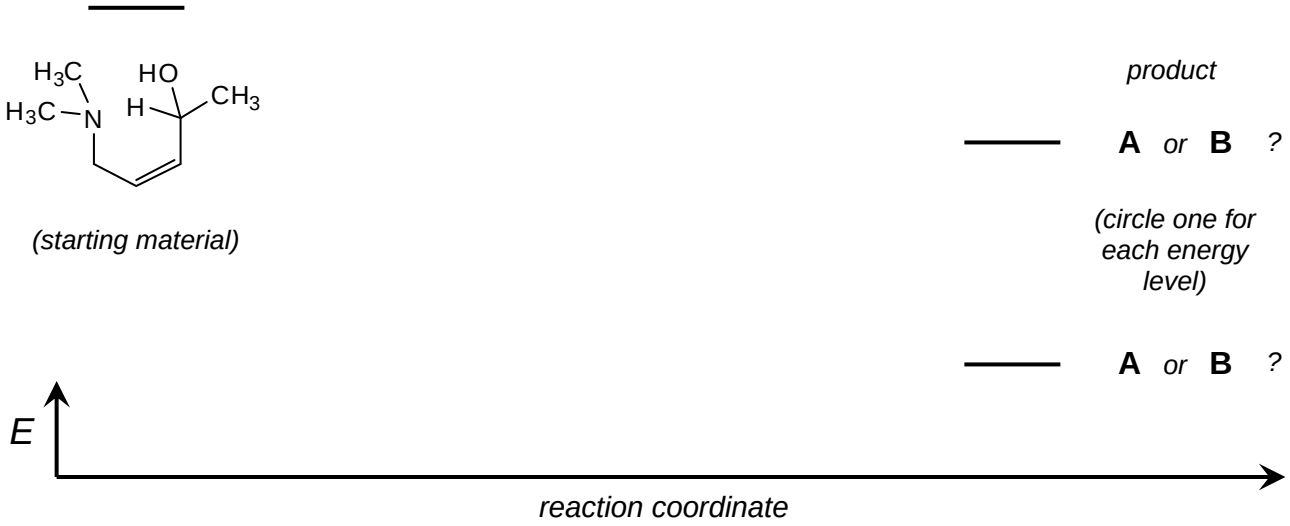


mechanism for product **B**



(c) On the diagram below, **draw potential energy curves for each of your two mechanisms**. For each curve:

- Draw energy levels for all transition states and intermediates, and connect them with curves. You do not need to draw any chemical structures, just energies.
- Energy levels for the starting material and the two products are given. Choose which product energy corresponds to which product, by circling one letter (**A** or **B**) for each.
- Because each mechanism is three steps long, you will need to draw two intermediates and three transition states on each curve.
- If your two mechanisms share any common intermediates or transition states, you only need to draw their (common) energy levels once.



Periodic Table of the Elements

Chemistry Reference Sheet

California Standards Test

	1 1A												13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1	1 **H** Hydrogen 1.01	2 2A																2 **He** Helium 4.00
2	3 **Li** Lithium 6.94	4 **Be** Beryllium 9.01											5 **B** Boron 10.81	6 **C** Carbon 12.01	7 **N** Nitrogen 14.01	8 **O** Oxygen 16.00	9 **F** Fluorine 19.00	10 **Ne** Neon 20.18
3	11 **Na** Sodium 22.99	12 **Mg** Magnesium 24.31	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 **Al** Aluminum 26.98	14 **Si** Silicon 28.09	15 **P** Phosphorus 30.97	16 **S** Sulfur 32.07	17 **Cl** Chlorine 35.45	18 **Ar** Argon 39.95
4	19 **K** Potassium 39.10	20 **Ca** Calcium 40.08	21 **Sc** Scandium 44.96	22 **Ti** Titanium 47.87	23 **V** Vanadium 50.94	24 **Cr** Chromium 52.00	25 **Mn** Manganese 54.94	26 **Fe** Iron 55.85	27 **Co** Cobalt 58.93	28 **Ni** Nickel 58.69	29 **Cu** Copper 63.55	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.72	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92	34 **Se** Selenium 78.96	35 **Br** Bromine 79.90	36 **Kr** Krypton 83.80
5	37 **Rb** Rubidium 85.47	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.91	40 **Zr** Zirconium 91.22	41 **Nb** Niobium 92.91	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.91	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.87	48 **Cd** Cadmium 112.41	49 **In** Indium 114.82	50 **Sn** Tin 118.71	51 **Sb** Antimony 121.76	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90	54 **Xe** Xenon 131.29
6	55 **Cs** Cesium 132.91	56 **Ba** Barium 137.33	57 **La** Lanthanum 138.91	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.95	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.21	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.22	78 **Pt** Platinum 195.08	79 **Au** Gold 196.97	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.38	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
7	87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (266)	107 **Bh** Bohrium (264)	108 **Hs** Hassium (269)	109 **Mt** Meitnerium (268)									

58 **Ce** Cerium 140.12	59 **Pr** Praseodymium 140.91	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.96	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.93	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.97
90 **Th** Thorium 232.04	91 **Pa** Protactinium 231.04	92 **U** Uranium 238.03	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Key

11 — Atomic number
Na — Element symbol
Sodium — Element name
22.99 — Average atomic mass*

* If this number is in parentheses, then it refers to the atomic mass of the most stable isotope.