NAME (Print): _____

SIGNATURE: _____

Chemistry 320M/328M
Dr. Brent Iverson
Final
December 16, 2017

Please print the first three letters of your last name in the three boxes

Please Note: This test may be a bit long, but there is a reason. I would like to give you a lot of little questions, so you can find ones you can answer and show me what you know, rather than just a few questions that may be testing the one thing you forgot. **I recommend you look the exam over and answer the questions you are sure of first**, then go back and try to figure out the rest. Also make sure to **look at the point totals** on the questions as a guide to help budget your time.

You cannot use a red pen to take the exam. You must have your answers written in PERMANENT ink if you want a regrade!!!! This means no test written in pencil or ERASABLE INK will be regraded.

Please note: We routinely xerox a number of exams following initial grading to guard against receiving altered answers during the regrading process.

FINALLY, DUE TO SOME UNFORTUNATE RECENT INCIDENCTS YOU ARE NOT ALLOWED TO INTERACT WITH YOUR CELL PHONE IN ANY WAY. IF YOU TOUCH YOUR CELL PHONE DURING THE EXAM YOU WILL GET A "0" NO MATTER WHAT YOU ARE DOING WITH THE PHONE. PUT IT AWAY AND LEAVE IT THERE!!!

Page	Points	
1		(29)
2		(26)
3		(20)
4		(15)
5		(-)
6		(-)
7		(-)
8		(28)
9		(19)
10		(23)
11		(29)
12		(20)
13		(32)
14		(37)
15		(30)
16		(16)
17		(17)
18		(16)
19		(13)
20		(10)
21		(8)
Total		(388)

Student Honor Code

"As a student of The University of Texas at Austin, I shall abide by the core values of the University and uphold academic integrity."

_____

(Your signature)

As you go through the test, I recommend that you:

1) Remain as relaxed and calm as possible throughout
2) Work problems worth the most points first
3) Concentrate on finishing all the problems you are most certain about
4) Leave the ones you have doubts about for last
5) Do not second guess yourself, you got this!

What a long and wonderful road it has been this semeter. We started with a review of general chemical structure and bonding then proceeded to develop an understanding of alkane conformations, relative acidities of different functional goups and stereochemistry of tetrahedral carbon. What followed was a comprehensive series of mechanisms and reactions, built around the notion that understanding the mechanisms, especially how they relate to the four common mechanistic elemental steps, provides an understanding of organic chemistry. Once you know the "personalities" of molecules, you can *predict* what they will do! The culmination of everything we have done is synthesis, that is, an ability to develop strategies to make more complex molecules from simpler ones. But this has always been about more than just Organic Chemistry. The high level thinking skills you develop while working synthesis problems for this class will be important to all of your futures, no matter what you intend to do.

I have very much enjoyed getting to know all of you. As one of my favorite poets of the 20th century put it: "May your wishes all come true. May you build a ladder to the stars and climb on every rung. May you stay forever young. May your heart always be joyful and may your song always be sung. And may you stay forever young." BD

Remember, run every chance you get. Being fit for your entire life is truly the best way to stay forever young.

Brent Iverson

Use this page to write down your roadmap if you would like.

Use this page for scratch if you would like. For your reference, here are the Golden Rules of Chemistry:

A. **Predicting Structure and Bonding** 1. In most stable molecules, all the atoms will have filled valence shells. 2. Five- and six-membered rings are the most stable. 3. There are two possible arrangements of four different groups around a tetrahedral atom.
B. **Predicting Stability and Properties** 4. The most important question in organic chemistry is "Where are the electrons?" 5. Delocalization of charge over a larger area is stabilizing. 6. Delocalization of unpaired electron density over a larger area is stabilizing. 7. Delocalization of pi electron density over a larger area is stabilizing.
C. **Predicting Reactions** 8. Reactions will occur if the products are more stable than the reactants and the energy barrier is low enough. 9. Functional groups react the same in different molecules. 10. A reaction mechanism describes the sequence of steps occurring during a reaction. 11. Most bond-making steps in reaction mechanisms involve nucleophiles reacting with electrophiles.

PERIODIC TABLE OF THE ELEMENTS

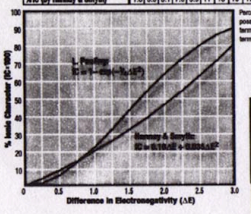
▼ Elementary Subatomic Particles

	Electron	Proton	Neutron	Photon	Neutrino
Symbol	e	P	n	γ	ν
Rest mass (kg)	9.1093897(54) x 10^{-31}	1.6726231(10) x 10^{-27}	1.6749286(10) x 10^{-27}	0	≈ 0
Molar mass (kg/mol)	5.48579903(13) x 10^{-7}	1.00727647(12) x 10^{-3}	1.00866494(14) x 10^{-3}	0	≈ 0
Particle-electron mass ratio	1	1836.152701(37)	1838.683662(40)	0	≈ 0
Particle-proton mass ratio	5.44617013(11) x 10^{-4}	1	1.001378404(9)	0	≈ 0
Particle-neutron mass ratio	5.438673x10−4	0.998624	1	0	≈ 0
Specific charge (C/kg)	−1.7588196240(53) x 10^{+11}	9.5788309(29) x 10^{+7}	0	0	0
Radius (m)	< 1 x 10^{-18}	8 x 10^{-16}	8 x 10^{-16}	0	≈ 0
Spin quantum number	1/2	1/2	1/2	1	1/2
Compton wavelength (m)	2.42631058(22) x 10^{-12}	1.32141002(12) x 10^{-15}	1.3195911012) x 10^{-5}	–	–
Magnetic moment (J/T): μ	928.477091(31) x 10^{-26}	1.41060761(47) x 10^{-26}	0.96623707(40) x 10^{-26}	0	0
In Bohr magnetons: μ/μB	1.00115965219310)	1.521032202(15) x 10^{-3}	1.04187563(25) x 10^{-3}	0	0
In nuclear magnetons: μ/μN	1838.282000(37)	2.79284736(83)	1.91304275(45)	0	0

Elementary particles are the fundamental constituents of energy and matter. The positron (e^+) is a positive-energy particle which has the same mass as an ordinary electron. The antineutrino ($\bar{\nu}$) has similar properties as that of a neutrino (ν) except its spin is directed along its direction of motion, whereas the neutrino's spin is always opposite to the direction of motion. Negative beta decay is the transformation of a neutron into a proton, a beta particle (negative electron) and a antineutrino ($n \rightarrow p + e^- + \bar{\nu}$). Positive beta decay involves the transformation of a proton into a neutron, a positron and a neutrino ($p \rightarrow n + \beta^+ + \nu$). The magnetic moment ($\mu_l$) of a particle can also be expressed as a dimensionless quantity by dividing it with either the Bohr magneton (μ_B = 9.2740154(31) x 10^{-24} J/T) or the nuclear magneton (μ_N = 5.0507866(17) x 10^{-27} J/T).

▼ % Ionic Character of a Single Chemical Bond

Difference in Electronegativity	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2
%IC (by L. Pauling)	0.2	1.0	2.2	3.9	6.1	8.6	12	15	18	22	26	30	34	39	43	47	51	56	59	63	67	70	73	76	79	82	84	86	88	89	91	92
%IC (by Hanney & Smyth)	1.0	3.3	5.1	7.0	8.9	11	13	15	17	20	22	24	27	29	32	35	37	40	43	46	49	52	55	59	62	65	68	72	76	80	83	87



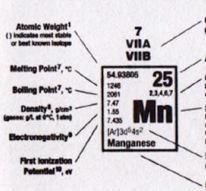
Percent ionic character describes the nature of a bond. Bonds possessing 50% or greater ionic character are commonly termed ionic; bonds with less than 50% ionic character are termed covalent. Pauling's equation was modified by Hanney & Smyth in order to achieve better agreement between experimental and calculated values. Transition from ionic to covalent binding is usually accompanied by a reduction in electrical conductance, melting point and boiling point.

1 IA IA																		18 VIII O
1.00794 −259.34 −252.87 0.0899 2.20 13.598 1s¹	1 I **H** Hydrogen	2 IIA IIA										13 IIIB IIIA	14 IVB IVA	15 VB VA	16 VIB VIA	17 VIIB VIIA	4.0026022 −272.2 (26 atm) −268.93 0.1785 – 24.587 1s²	2 **He** Helium
6.941 180.5 1342 0.534 0.98 5.392 [He]2s¹	3 **Li** Lithium	9.012182 1287 2471 1.8477 1.57 9.322 [He]2s²	4 **Be** Beryllium									10.811 2075 4000 2.31 2.04 8.298 [He]2s²2p¹	5 **B** Boron	12.011 4492* 3825* 2.25 2.55 11.260 [He]2s²2p²	6 2,±4 **C** Carbon	14.00674 -210.00 -195.79 1.25046 3.04 14.534 [He]2s²2p³	7 2,±3,4,5 **N** Nitrogen	15.9994 -218.79 -182.95 1.429 3.44 13.618 [He]2s²2p⁴	8 −2 **O** Oxygen	18.9984032 -219.62 -188.12 1.69 3.98 17.422 [He]2s²2p⁵	9 −1 **F** Fluorine	20.1797 -248.59 -246.08 0.9002 – 21.564 [He]2s²2p⁶	10 **Ne** Neon
22.989768 97.72 883 0.97 0.93 5.139 [Ne]3s¹	11 **Na** Sodium	24.3050 650 1090 1.74 1.31 7.646 [Ne]3s²	12 **Mg** Magnesium									26.981539 660.32 2519 2.702 1.61 5.986 [Ne]3s²3p¹	13 3 **Al** Aluminum	28.0855 1414 3265* 2.33 1.90 8.151 [Ne]3s²3p²	14 4 **Si** Silicon	30.973762 44.15 277 1.82 2.19 10.486 [Ne]3s²3p³	15 3,±3,4,5 **P** Phosphorus	32.066 115.21 444.60 2.07 2.58 10.360 [Ne]3s²3p⁴	16 ±2,4,6 **S** Sulfur	35.4527 -101.5 -34.04 3.214 3.16 12.967 [Ne]3s²3p⁵	17 ±1,3,5,7 **Cl** Chlorine	39.948 -189.35 -185.85 1.784 – 15.759 [Ne]3s²3p⁶	18 **Ar** Argon
39.0983 63.38 759 0.86 0.82 4.341 [Ar]4s¹	19 **K** Potassium	40.078 842 1484 1.54 1.00 6.113 [Ar]4s²	20 2 **Ca** Calcium	44.955910 1541 2830 2.989 1.36 6.54 [Ar]3d¹4s²	21 3 **Sc** Scandium	47.88 1668 3287 4.5 1.54 6.82 [Ar]3d²4s²	22 3,4 **Ti** Titanium	50.9415 1910 3407 5.96 1.63 6.74 [Ar]3d³4s²	23 2,3,4,5 **V** Vanadium	51.9961 1907 2671 7.20 1.66 6.766 [Ar]3d⁵4s¹	24 2,3,6 **Cr** Chromium	54.93805 1246 2061 7.47 1.55 7.435 [Ar]3d⁵4s²	25 2,3,4,6,7 **Mn** Manganese	55.847 1538 2861 7.86 1.83 7.870 [Ar]3d⁶4s²	26 2,3 **Fe** Iron	58.93320 1495 2927 8.92 1.88 7.86 [Ar]3d⁷4s²	27 2,3 **Co** Cobalt	58.6934 1455 2913 8.90 1.91 7.635 [Ar]3d⁸4s²	28 2,3 **Ni** Nickel	63.546 1084.62 2562 8.94 1.90 7.726 [Ar]3d¹⁰4s¹	29 1,2 **Cu** Copper	65.39 419.53 907 7.14 20°C 1.65 9.394 [Ar]3d¹⁰4s²	30 2 **Zn** Zinc	69.723 29.76 2204 6.095 1.81 5.999 [Ar]3d¹⁰4s²4p¹	31 3 **Ga** Gallium	72.61 938.25 2833 5.35 2.01 7.899 [Ar]3d¹⁰4s²4p²	32 4 **Ge** Germanium	74.92159 817* 614* 5.727 25°C 2.18 9.81 [Ar]3d¹⁰4s²4p³	33 ±3,5 **As** Arsenic	78.96 221 685 4.81 2.55 9.752 [Ar]3d¹⁰4s²4p⁴	34 -2,4,6 **Se** Selenium	79.904 -7.2 58.8 3.119 2.96 11.814 [Ar]3d¹⁰4s²4p⁵	35 ±1,5 **Br** Bromine	83.80 -157.36 -153.22 3.74 – 13.999 [Ar]3d¹⁰4s²4p⁶	36 **Kr** Krypton
85.4678 38.31 688 1.532 0.82 4.177 [Kr]5s¹	37 **Rb** Rubidium	87.62 777 1382 2.6 0.95 5.695 [Kr]5s²	38 2 **Sr** Strontium	88.90585 1526 3345 4.469 1.22 6.38 [Kr]4d¹5s²	39 3 **Y** Yttrium	91.224 1855 4409 6.49 1.33 6.84 [Kr]4d²5s²	40 4 **Zr** Zirconium	92.90638 2477 4744 8.57 1.6 6.9 [Kr]4d⁴5s¹	41 3,5 **Nb** Niobium	95.94 2623 4639 10.2 2.16 7.099 [Kr]4d⁵5s¹	42 2,3,4,5,6 **Mo** Molybdenum	(97.9072) 2157 4265 11.5 1.9 7.28 [Kr]4d⁵5s²	43 7 **Tc** Technetium	101.07 2334 4150 12.3 2.2 7.37 [Kr]4d⁷5s¹	44 2,3,4,6,8 **Ru** Ruthenium	102.90550 1964 3695 12.4 2.28 7.46 [Kr]4d⁸5s¹	45 2,3,4 **Rh** Rhodium	106.42 1554.9 2963 12.02 2.20 8.34 [Kr]4d¹⁰	46 2,4 **Pd** Palladium	107.8682 961.78 2162 10.5 1.93 7.576 [Kr]4d¹⁰5s¹	47 1 **Ag** Silver	112.411 321.07 767 8.642 1.69 8.993 [Kr]4d¹⁰5s²	48 2 **Cd** Cadmium	114.818 156.60 2072 7.30 1.78 5.786 [Kr]4d¹⁰5s²5p¹	49 1,3 **In** Indium	118.710 231.93 2602 7.28 1.96 7.344 [Kr]4d¹⁰5s²5p²	50 2,4 **Sn** Tin	121.757 630.63 1587 6.684 25°C 2.05 8.641 [Kr]4d¹⁰5s²5p³	51 ±3,5 **Sb** Antimony	127.60 449.51 988 6.25 2.1 9.009 [Kr]4d¹⁰5s²5p⁴	52 -2,4,6 **Te** Tellurium	126.90447 113.7 184.4 4.93 2.66 10.451 [Kr]4d¹⁰5s²5p⁵	53 ±1,5,7 **I** Iodine	131.29 -111.75 -108.04 5.89 – 12.130 [Kr]4d¹⁰5s²5p⁶	54 **Xe** Xenon
132.90543 28.44 671 1.879 0.79 3.894 [Xe]6s¹	55 **Cs** Cesium	137.327 1897 3284 3.59 0.89 5.212 [Xe]6s²	56 2 **Ba** Barium	138.9055 920 3455 6.146 1.10 5.577 [Xe]5d¹6s²	57 3 **La** Lanthanum	178.49 2233 4603 13.31 1.3 7.0 [Xe]4f¹⁴5d²6s²	72 4 **Hf** Hafnium	180.9479 3017 5458 16.6 1.5 7.89 [Xe]4f¹⁴5d³6s²	73 5 **Ta** Tantalum	183.84 3422 5555 19.35 2.36 7.98 [Xe]4f¹⁴5d⁴6s²	74 2,3,4,5,6 **W** Tungsten	186.207 3186 5596 20.5 1.9 7.88 [Xe]4f¹⁴5d⁵6s²	75 −1,2,4,6,7 **Re** Rhenium	190.23 3033 5012 22.61 2.2 8.7 [Xe]4f¹⁴5d⁶6s²	76 2,3,4,6,8 **Os** Osmium	192.22 2446 4428 22.65 2.20 9.1 [Xe]4f¹⁴5d⁷6s²	77 2,3,4,6 **Ir** Iridium	195.08 1768.4 3825 21.45 2.28 9.0 [Xe]4f¹⁴5d⁹6s¹	78 2,4 **Pt** Platinum	196.96654 1064.18 2856 19.31 2.54 9.225 [Xe]4f¹⁴5d¹⁰6s¹	79 1,3 **Au** Gold	200.59 -38.83 356.73 13.546 2.00 10.437 [Xe]4f¹⁴5d¹⁰6s²	80 1,2 **Hg** Mercury	204.3833 304 1473 11.85 2.04 6.108 [Xe]4f¹⁴5d¹⁰6s²6p¹	81 1,3 **Tl** Thallium	207.2 327.46 1749 11.34 2.33 7.416 [Xe]4f¹⁴5d¹⁰6s²6p²	82 2,4 **Pb** Lead	208.98037 271.40 1564 9.78 2.02 7.289 [Xe]4f¹⁴5d¹⁰6s²6p³	83 3,5 **Bi** Bismuth	(208.9824) 254 962 9.196 2.0 8.42 [Xe]4f¹⁴5d¹⁰6s²6p⁴	84 2,4 **Po** Polonium	(209.9871) 302 – – 2.2 – [Xe]4f¹⁴5d¹⁰6s²6p⁵	85 ±1,3,5,7 **At** Astatine	(222.0176) -71 -61.7 9.73 – 10.748 [Xe]4f¹⁴5d¹⁰6s²6p⁶	86 **Rn** Radon
(223.0197) 27 677 – 0.7 – [Rn]7s¹	87 1 **Fr** Francium	(226.0254) 5.0 ≈1140 5.0 0.9 5.279 [Rn]7s²	88 2 **Ra** Radium	(227.0278) 1051 2198 10.07 1.1 6.9 [Rn]6d¹7s²	** 89 3 **Ac** Actinium	(261.11) – – – – – [Rn]5f¹⁴6d²7s²	104 4 **Unq** Unnilquadium	(262.114) – – – – – [Rn]5f¹⁴6d³7s²	105 **Unp** Unnilpentium	(263.118) – – – – – [Rn]5f¹⁴6d⁴7s²	106 **Unh** Unnilhexium	(262.12) – – – – – [Rn]5f¹⁴6d⁵7s²	107 **Uns** Unnilseptium	(265) – – – – – [Rn]5f¹⁴6d⁶7s²	108 **Uno** Unniloctium	(266) – – – – – [Rn]5f¹⁴6d⁷7s²	109 **Une** Unnilennium	(272) – – – – – [Rn]5f¹⁴6d¹⁰7s²	110 **Uun** Ununnium												

The data for this reference guide were obtained from the latest scientific and governmental sources (IUPAC, CODATA, National Bureau of Standards, etc.). Italicized values and/or inconsistent data are marked with an asterisk (*).

1. Ratio of the average mass per atom of the element to 1/12 of the mass of an atom of ^{12}C. Round brackets indicate atomic weight of the most stable or best known isotope. 2. Number of protons in the nucleus of each atom of an element. 3. Number of charges an atom would have in a molecule (or an ionic compound) if electrons were transferred completely. 4. Names and symbols of elements 104-110 are those recommended by the International Union of Pure and Applied Chemistry (IUPAC)—alternative names have been proposed by other groups. 5. Distribution of electrons among the various atomic orbitals. 6. Two-letter group classifications systems still in use today rely on an A/B numbering scheme to categorize periodic properties. Because of the potential for confusion between these two systems (i.e., VIA in one scheme is equal to VIB in the other), IUPAC recommends the use of an unambiguous 1-18 group classification system. 7. Melting point: temperature at which solid and liquid phases coexist in equilibrium. Boiling point: temperature at which the vapor pressure of a liquid is equal to the external atmospheric pressure. Unless otherwise stated values are at 1 atm; SP = sublimation point at 1 atm; TP = triple point. 8. Mass of the substance divided by its volume (g/cm³ at 20°C for gases: g/L at 0°C, 1 atm). 9. Relative measure of the attraction of an atom in a chemical bond for the shared electrons. 10. Minimum energy to remove an electron from an isolated atom in its ground state (1eV = 96.487 kJ/mol).

*Indicates approximate values and/or inconsistent literature data.



●	140.115 799 3424 6.770 1.12 5.466 [Xe]4f¹5d¹6s²	58 3,4 **Ce** Cerium	140.90765 931 3510 6.773 1.13 5.422 [Xe]4f³6s²	59 3,4 **Pr** Praseodymium	144.24 1016 3056 7.00 1.14 5.489 [Xe]4f⁴6s²	60 3 **Nd** Neodymium	(144.9127) 1042 3000 7.264 1.13 5.554 [Xe]4f⁵6s²	61 3 **Pm** Promethium	150.36 1072 1730 7.536 1.17 5.631 [Xe]4f⁶6s²	62 2,3 **Sm** Samarium	151.965 822 1596 5.244 1.2 5.606 [Xe]4f⁷6s²	63 2,3 **Eu** Europium	157.25 1314 3264 7.901 1.20 6.141 [Xe]4f⁷5d¹6s²	64 3 **Gd** Gadolinium	158.92534 1359 3221 8.230 1.22 5.842 [Xe]4f⁹6s²	65 3,4 **Tb** Terbium	162.50 1411 2561 8.551 1.22 5.927 [Xe]4f¹⁰6s²	66 3 **Dy** Dysprosium	164.93032 1472 2694 8.80 1.23 6.018 [Xe]4f¹¹6s²	67 3 **Ho** Holmium	167.26 1529 2862 9.066 1.25 6.101 [Xe]4f¹²6s²	68 3 **Er** Erbium	168.93421 1545 1946 9.321 1.25 6.18436 [Xe]4f¹³6s²	69 2,3 **Tm** Thulium	173.04 824 1194 6.966 1.1 6.25394 [Xe]4f¹⁴6s²	70 2,3 **Yb** Ytterbium	174.967 1663 3393 9.84 1.27 5.42589 [Xe]4f¹⁴5d¹6s²	71 3 **Lu** Lutetium
●●	232.0381 1750 4788 11.72 1.3 6.08 [Rn]6d²7s²	90 4 **Th** Thorium	231.03588 1572 – 15.37 1.5 5.89 [Rn]5f²6d¹7s²	91 4,5 **Pa** Protactinium	238.0289 1135 4131 19.05 ±0.02 1.38 6.05 [Rn]5f³6d¹7s²	92 3,4,5,6 **U** Uranium	(237.0482) 644 3909 20.45 1.36 6.19 [Rn]5f⁴6d¹7s²	93 3,4,5,6 **Np** Neptunium	(244.0642) 640 3228 19.816 1.28 5.8 [Rn]5f⁶7s²	94 3,4,5,6 **Pu** Plutonium	(243.0614) 1176 3counted 13.67 1.3 5.993 [Rn]5f⁷7s²	95 3,4,5,6 **Am** Americium	(247.0703) 1345 – 13.51 1.3 6.02 [Rn]5f⁷6d¹7s²	96 3 **Cm** Curium	(247.0703) 1050 – 14.78 1.3 6.23 [Rn]5f⁹7s²	97 3,4 **Bk** Berkelium	(251.0796) 900 – – 1.3 6.30 [Rn]5f¹⁰7s²	98 3 **Cf** Californium	(252.083) 860 – – 1.3 6.42 [Rn]5f¹¹7s²	99 3 **Es** Einsteinium	(257.0951) 1527 – – 1.3 6.50 [Rn]5f¹²7s²	100 3 **Fm** Fermium	(258.10) 827 – – 1.3 6.58 [Rn]5f¹³7s²	101 2,3 **Md** Mendelevium	(259.1009) 827 – – 1.3 6.65 [Rn]5f¹⁴7s²	102 2,3 **No** Nobelium	(262.11) 1627 – – – – [Rn]5f¹⁴6d¹7s²	103 3 **Lr** Lawrencium

PAPERTECH

Editors: T. K. Varga, M.A.Sc. & C. Bello, M.A.Sc.

Product No. LCH-04F

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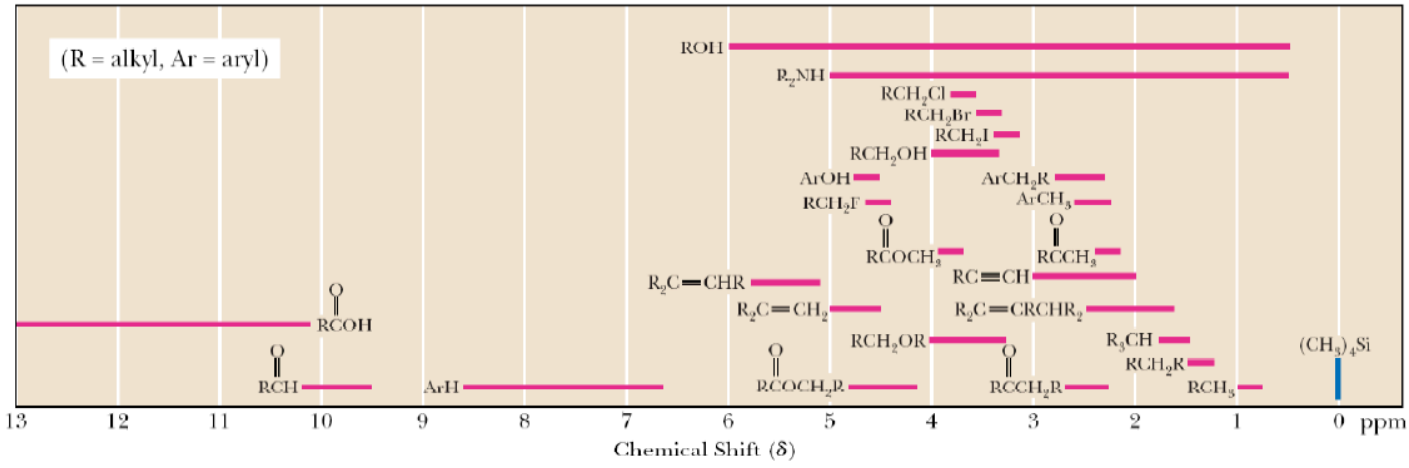
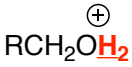
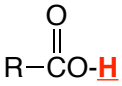
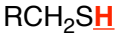
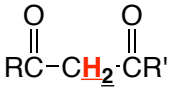
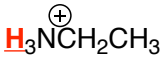
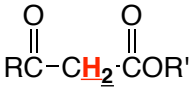
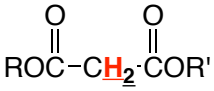
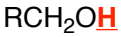
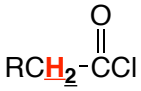
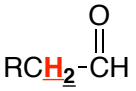
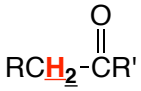
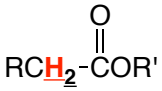
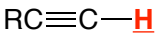
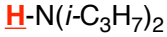
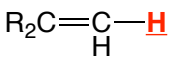
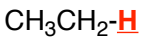
Type of Hydrogen (R = alkyl, Ar = aryl)	Chemical Shift (δ)*	Type of Hydrogen (R = alkyl, Ar = aryl)	Chemical Shift (δ)*
R_2NH	0.5-5.0	RCH_2OH	3.4-4.0
ROH	0.5-6.0	RCH_2Br	3.4-3.6
RCH_3	0.8-1.0	RCH_2Cl	3.6-3.8
RCH_2R	1.2-1.4	$RCOCH_3$	3.7-3.9
R_3CH	1.4-1.7	$RCOCH_2R$	4.1-4.7
$R_2C{=}CRCHR_2$	1.6-2.6	RCH_2F	4.4-4.5
$RC{\equiv}CH$	2.0-3.0	$ArOH$	4.5-4.7
$RCCH_3$	2.1-2.3	$R_2C{=}CH_2$	4.6-5.0
$RCCH_2R$	2.2-2.6	$R_2C{=}CHR$	5.0-5.7
$ArCH_3$	2.2-2.5	$H_2C{-}CH_2$	3.3-4.0
RCH_2NR_2	2.3-2.8	RCH	9.5-10.1
RCH_2I	3.1-3.3	$RCOH$	10-13
RCH_2OR	3.3-4.0		

* Values are relative to tetramethylsilane. Other atoms within the molecule may cause the signal to appear outside these ranges.



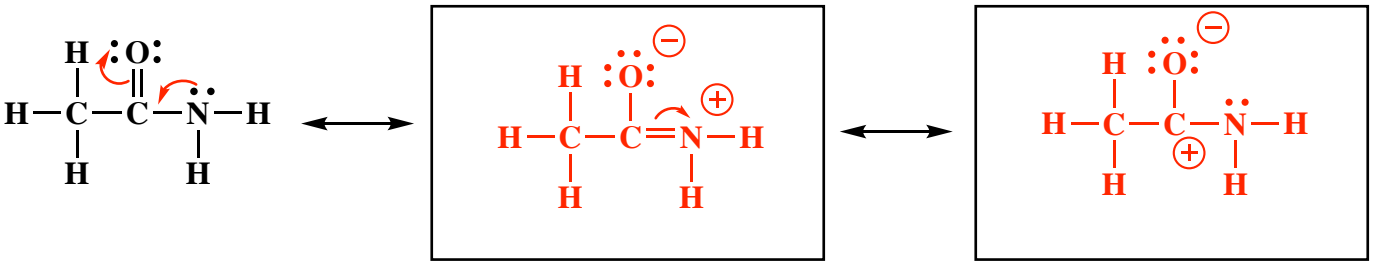
Compound		pK_a
Hydrochloric acid		-7
Protonated alcohol		-2
Hydronium ion		-1.7
Carboxylic acids		3-5
Thiols		8-9
Ammonium ion		9.2
β-Dicarbonyls		10
Primary ammonium		10.5
β-Ketoesters		11
β-Diesters		13
Water		15.7
Alcohols		15-19
Acid chlorides		16
Aldehydes		18-20
Ketones		18-20
Esters		23-25
Terminal alkynes		25
LDA		40
Terminal alkenes		44
Alkanes		51

Signature_____ Pg 1 _____(29)

1. (5 pts) What is the most important question in organic chemistry?

Where are the electrons?

2. (10 pts) Amides are best represented as the hybrid of three contributing structures. Draw the second and third important contributing structures in the spaces provided, including all lone pairs and formal charges. For the two structures on the left in each problem, use arrows to indicate the movement of electrons to give the structures you drew. There is no need to draw any circles around any of these contributing strucures. You might want to read these directions again to make sure you know what we want

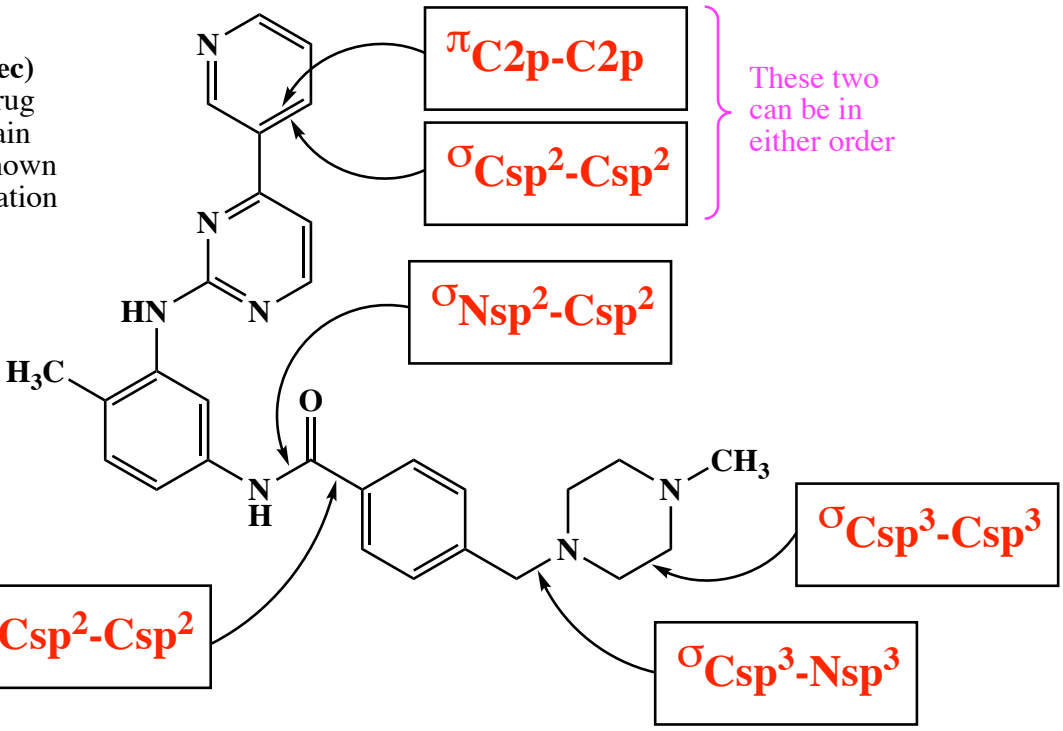


3. (14 points) Suppose a relative of yours is having an MRI. In no more than four sentences, explain to them what is happening when they have the MRI scan. We will be looking for a minumum of 7 key points here and your answer should match a recent Rule of the Day.

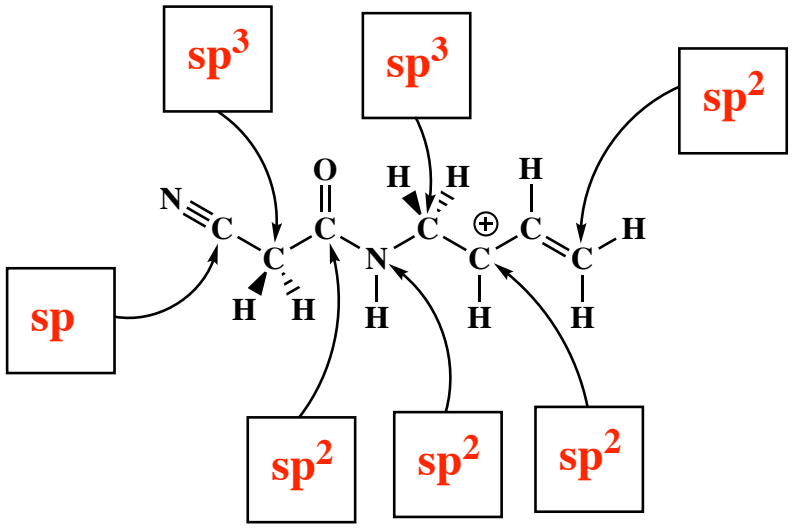
The popular medical diagnostic technique of **magnetic resonance imaging (MRI)** is based on the **same principles as NMR**, namely the **flipping (i.e. resonance) of nuclear spins of H atoms** by **radio frequency irradiation** when a patient is placed in a **strong magnetic field**. **Magnetic field gradients** are used to gain imaging information, and **rotation of the gradient around the center of the object** gives imaging in an entire plane (i.e. **slice inside patient**). In an MRI image, you are looking at **individual slices** that **when stacked make up the three-dimensional image** of **relative amounts of H atoms, especially the H atoms from water and fat, in the different tissues**.

4. (2 pts each) In the spaces provided, indicate the type of bond, and the hybridized orbitals that overlap to form the bond. For example, one answer could be: $\sigma Csp^3\text{-}H1s$

Imatinib (Gleevec)
An anti-cancer drug used to treat certain cancers with a known kinase gene alteration



5. (2 pts each) In the spaces provided, write the hybridization state of the atoms indicated by the arrow.



6. (2 pt each) **Circle whether each of the following statements is true or false.** You may notice these resemble Rules of the Day! These are worth a lot of points so please take your time and be careful. Read them carefully, but do not second guess yourself as we are not trying to trick you.

True **False** **A.** When the 2s orbital is hybridized with all three 2p orbitals, you get sp^3 hybridization that has major lobes pointed in a tetrahedral geometry.

True **False** **B.** When the 2s orbital is hybridized with all three 2p orbitals, you get sp^2 hybridization that has major lobes pointed in a trigonal planar geometry.

True **False** **C**. When three parallel 2p orbitals on adjacent atoms combine, three new molecular orbitals are produced (bonding, non-bonding and antibonding).

True **False** **D.** When a Lewis acid and Lewis base combine, the product is referred to as a Lewis acid-Lewis base complex. The new bond is referred to as a "coordinate covalent bond" or "dative bond".

True **False** **E** The enol form of a compound rapidly tautomerizes to the more stable keto form.

True **False** **F** The keto form of a compound rapidly tautomerizes to the more stable enol form.

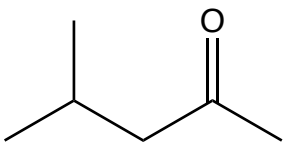
True **False** **G.** Nuclei with spin quantum number 1.0 are quantized in one of two orientations, "+1/2" (lower energy) or "-1/2"(higher energy) in the presence of an external magnetic field, that is, with and against the external field, respectively.

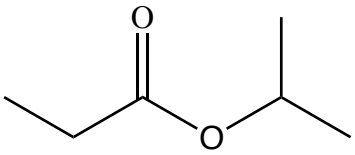
True **False** **H.** Nuclei with spin quantum number 1/2 are quantized in one of two orientations, "+1/2" (lower energy) or "-1/2"(higher energy) in the presence of an external magnetic field, that is, with and against the external field, respectively.

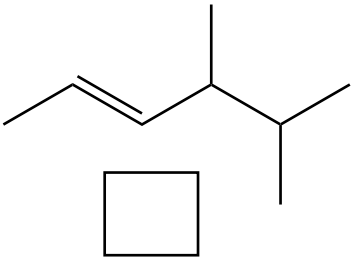
True **False** **I.** The difference in energy between the +1/2 and -1/2 nuclear spin states is proportional to the strength of the magnetic field felt by the nucleus.

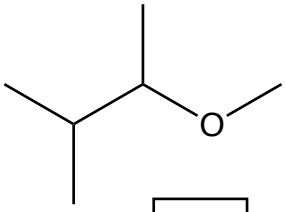
True **False** **J.** Running 3-5 miles a week EVERY WEEK as an adult dramatically increases your fitness level and improves your heatlh throughout your life. Doing this and enjoying a healthy life is even more important than getting an A on this organic final!

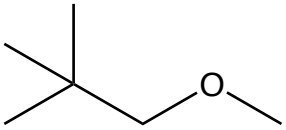
7. (15 pts total) On the following three pages there are NMR spectra. The relative integrations are given above each signal. Each NMR spectrum has a letter on it. **In the spaces provided, write the appropriate letter underneath the molecules that would produce that spectrum.** Notice that not all of the molecules below will have letters underneath them, as there are only three spectra but nine molecules.



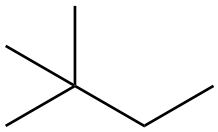


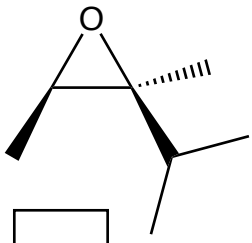


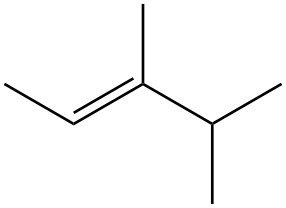




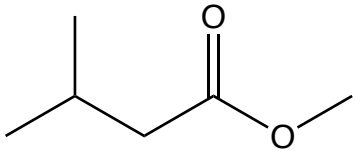
A





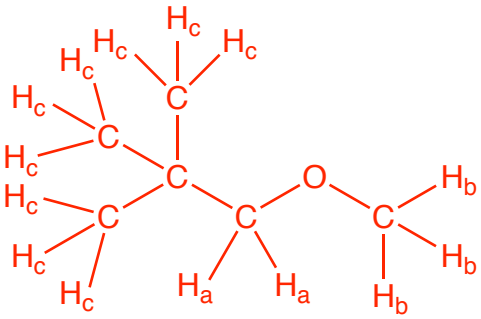


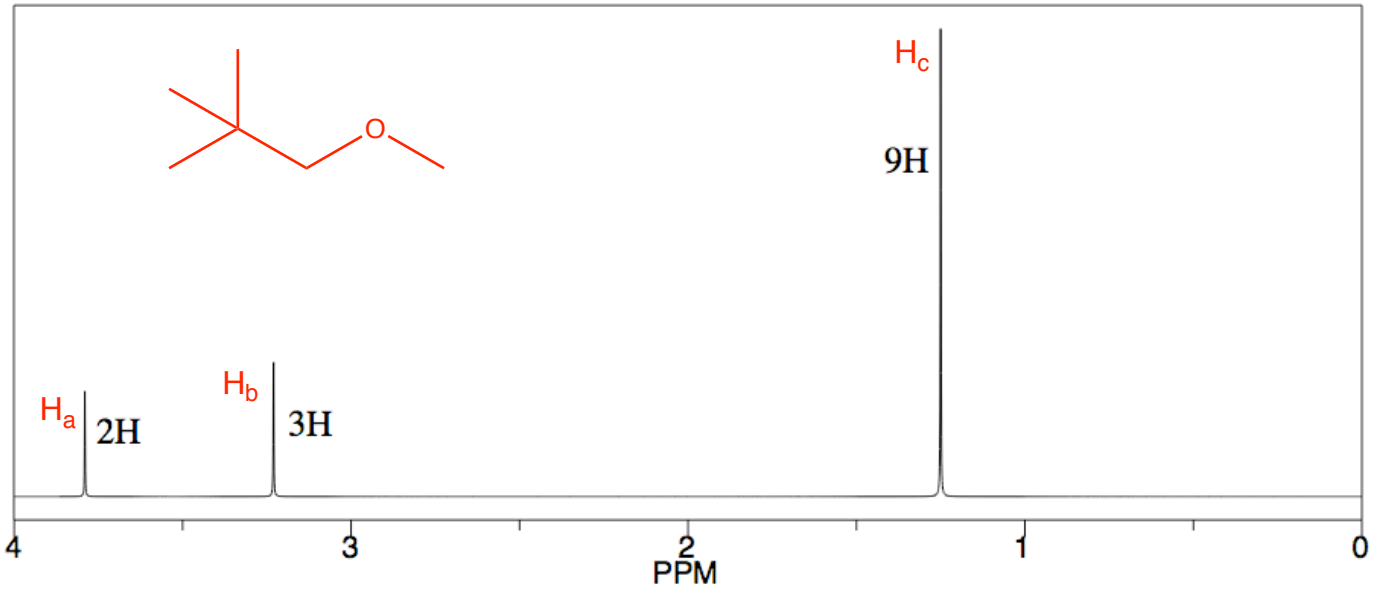
C



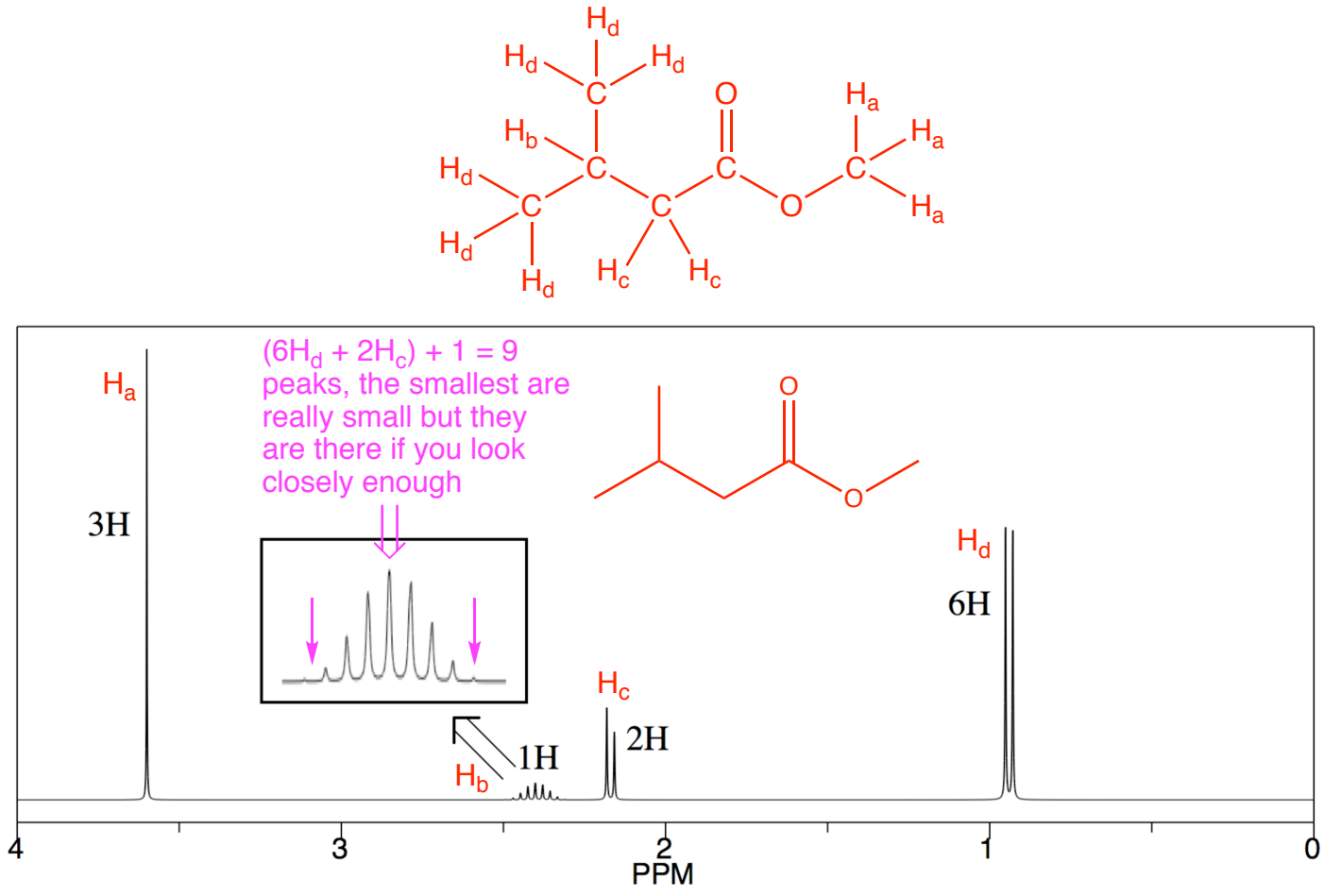
B

Spectrum A

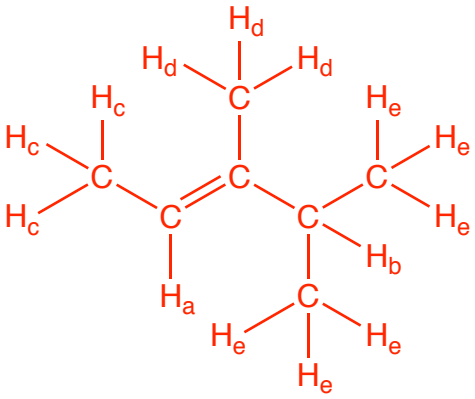

Hc
Hc
Hc
Hc
C
Hc
C
Hc
C
O
Hb
Hc
C
C
C
Hb
Hc
Hc
Ha
Ha
Hb

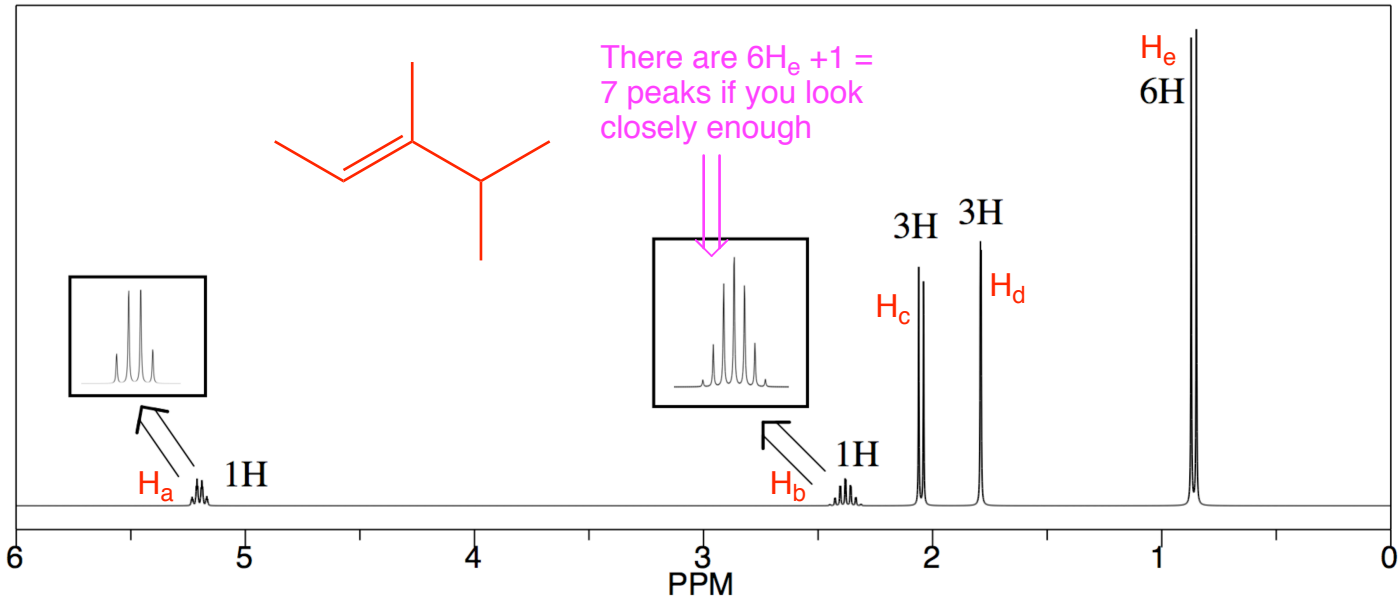

O
Hc
9H
Ha
2H
Hb
3H
4
3
2
1
0
PPM

Spectrum B

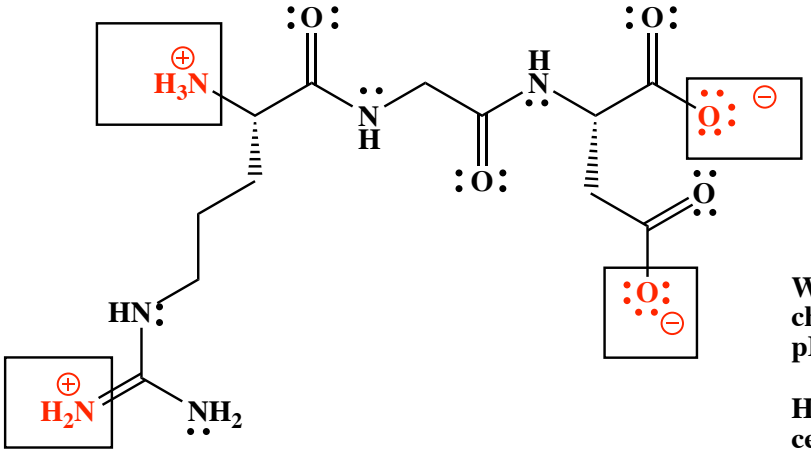

H_d
H_d
H_d
C
O
H_a
H_b
C
C
C
H_a
H_d
C
C
O
H_a
H_d
H_d
H_c
H_c
$(6H_d + 2H_c) + 1 = 9$ peaks, the smallest are really small but they are there if you look closely enough
H_a
3H
O
O
H_d
6H
H_c
2H
H_b
1H
4
3
2
1
0
PPM

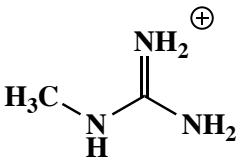
Spectrum C


Hd
Hd
Hd
C
Hc
Hc
Hc
C
C
C
He
He
He
C
C
C
Hb
Ha
C
He
He
He


There are 6He +1 = 7 peaks if you look closely enough
He
6H
3H
3H
Hc
Hd
Ha
1H
Hb
1H
6
5
4
3
2
1
0
PPM

8. The following molecule is called RGD. It is the most common peptide motif responsible for for cell adhesion to the extracellular matrix. Cell adhesion proteins called integrins recognize and bind the RGD sequence. **In the boxes, fill in the proper number of bonds to H atoms, lone pairs, and formal charges to show the protonation state of RGD at pH 7.0.** Use the pK_a table provided at the beginning of the test for reference as well as the reference pK_a provided on the right.





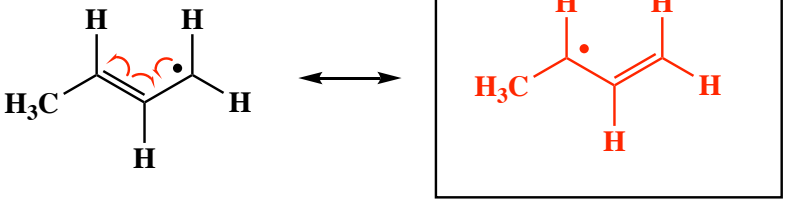
pK_a = 13.6

What is the total net charge of this peptide at pH 7.0? **0**

How many chiral centers are present in the RGD peptide? **2**

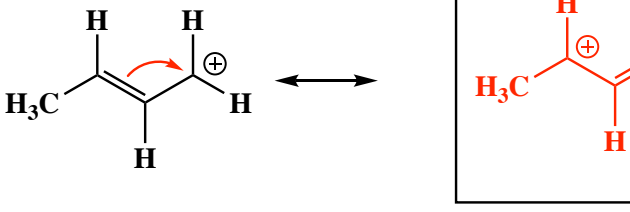
9. (16 pts total) The following are contributing structures for important resonance hybrids. Draw the other important resonance contributing structure in the box provided. Draw arrows on the structures on the left that indicate the flow of electrons that produce the contributing structures you drew to the right. Be sure to show all lone pairs and formal charges.

A.



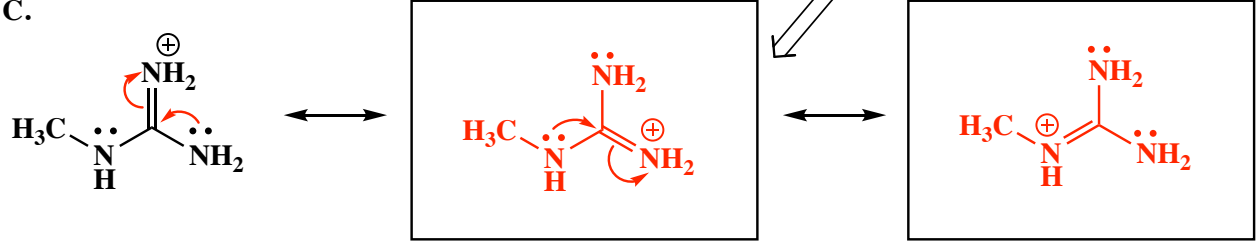
Did you remember to put arrows on the structures on the left?

B.



Yes, put arrow(s) on this structure to show how it is transformed to the structure to the far right!

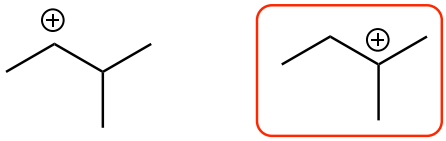
C.



10. (19 pts) Circle the appropriate structure from each pair, then fill in the blank on the right stating the reason(s) for your answer. Possible answers for the blanks on the right are **Inductive Effect**, **Angle Strain**, **Torsional Strain**, **Ring Strain, Steric Strain**, or **Hyperconjugation.** You might need more than one answer in some cases.

Reason(s)

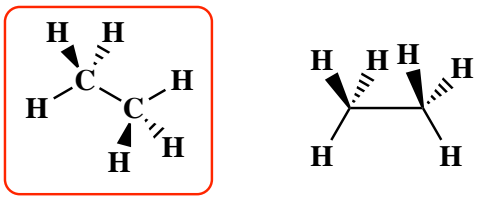
A) Circle the more stable carbocation



When it comes to stabilizing alkyl cations, these two go together as distinct but reinforcing stabilization mechanisms. Remember a C+ atom is electronegative compared to a neutral C atom

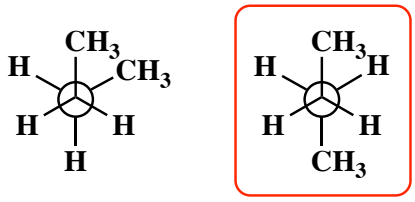
Hyperconjugation, Inductive Effect

B) Circle the more stable conformation



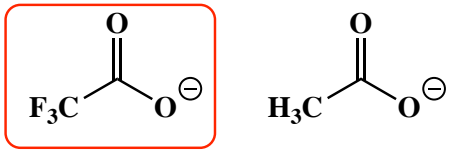
Torsional Strain

C) Circle the more stable conformation



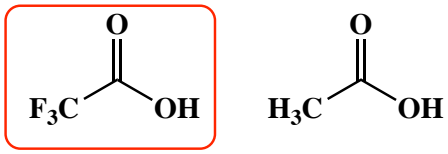
Steric Strain

D) Circle the more stable anion



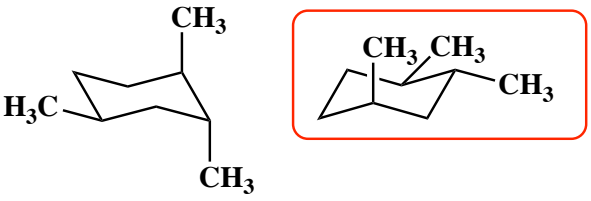
Inductive Effect

E) Circle the more acidic molecule



Inductive Effect

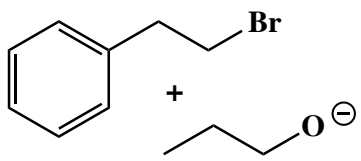
F) Circle the more stable conformation



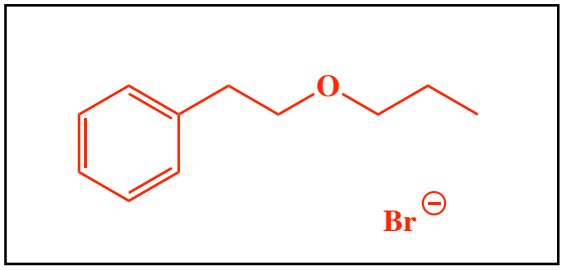
Steric Strain

11. (5, 6 or 8 pts each) The following reactions all involve chemistry of haloalkanes. **Fill in the box above the arrow with the mechanism that will be followed (S_N2, E2, etc.). Then draw only the predominant product or products** and please remember that **you must draw the correct stereoisomers**. For S_N1/E1 reactions you must draw all significant products (including all stereoisomers).

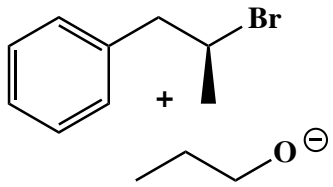
A.



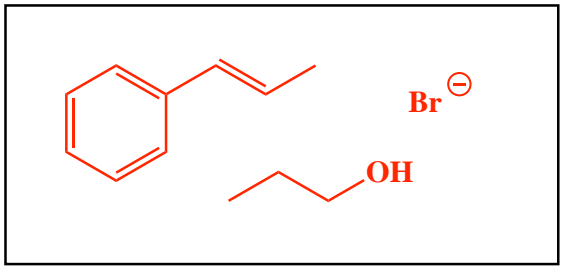
S_N2



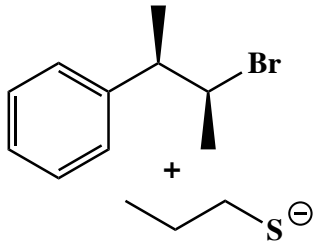
B.



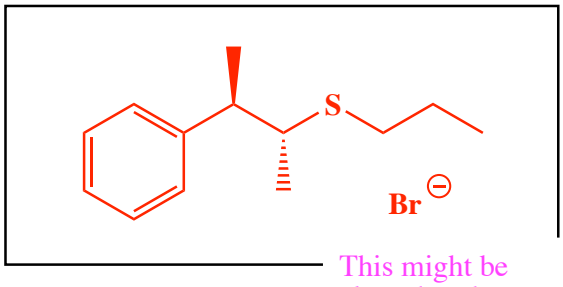
E2



C.

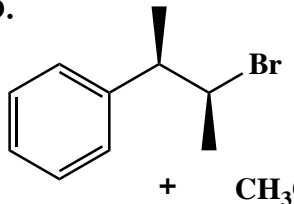


S_N2



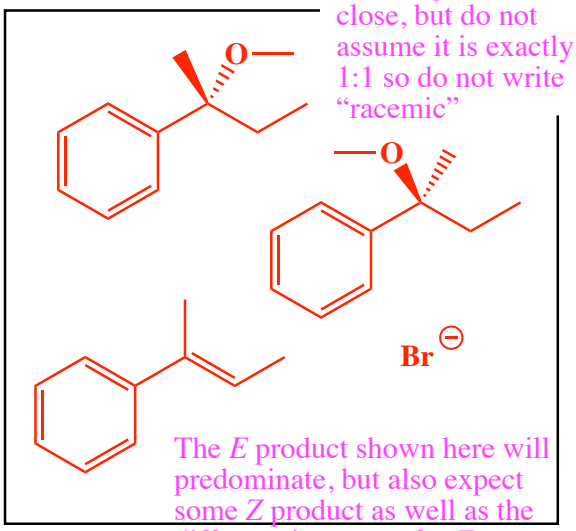
For the last one only draw rearranged products

D.



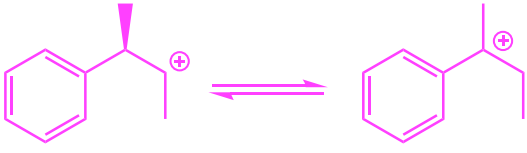
S_N1 / E1

(asssume rearrangement)



This might be close, but do not assume it is exactly 1:1 so do not write "racemic"

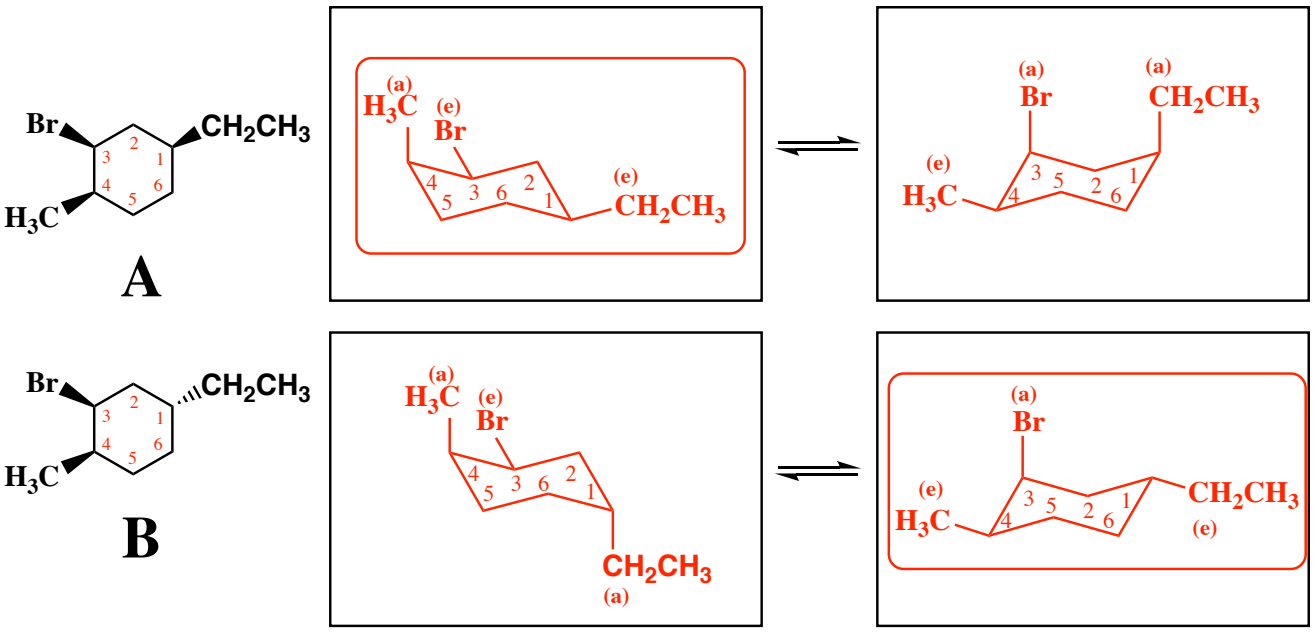
The *E* product shown here will predominate, but also expect some *Z* product as well as the differene in energy for *E* versus *Z* will be relatively small



Initially formed 2° carbocation

Rearrangement (1,2 H atom shift) gives the more stable 3° carbocation

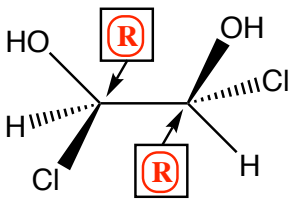
12. (10 pts) In the two spaces to the right, draw the two equilibrating chair structures for the following cyclohexane derivatives. In each case circle the one that predominates at equilibrium.

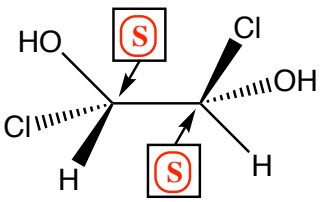


(3 pts) **Which of the two structures, A or B, will react faster in an E2 reaction?** **B**

(3 pts) **Your answer to that last question is based on noticing that for the molecule you chose, in the chair conformation that predominates, the Br atom is** **axial**

13. (13 pts total) On the line provided, state the stereochemical relationship between each pair of molecules: **enantiomers, diastereomers, or the same molecule**. In each box assign R and S to each chiral center to help answer this question. **Circle all meso compounds.**

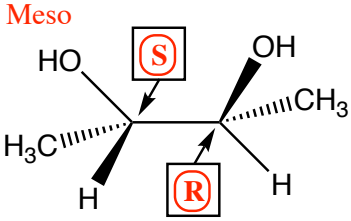


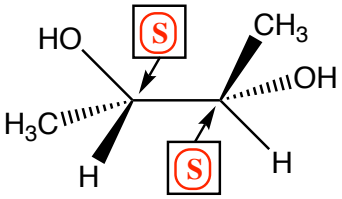


Relationship

Enantiomers

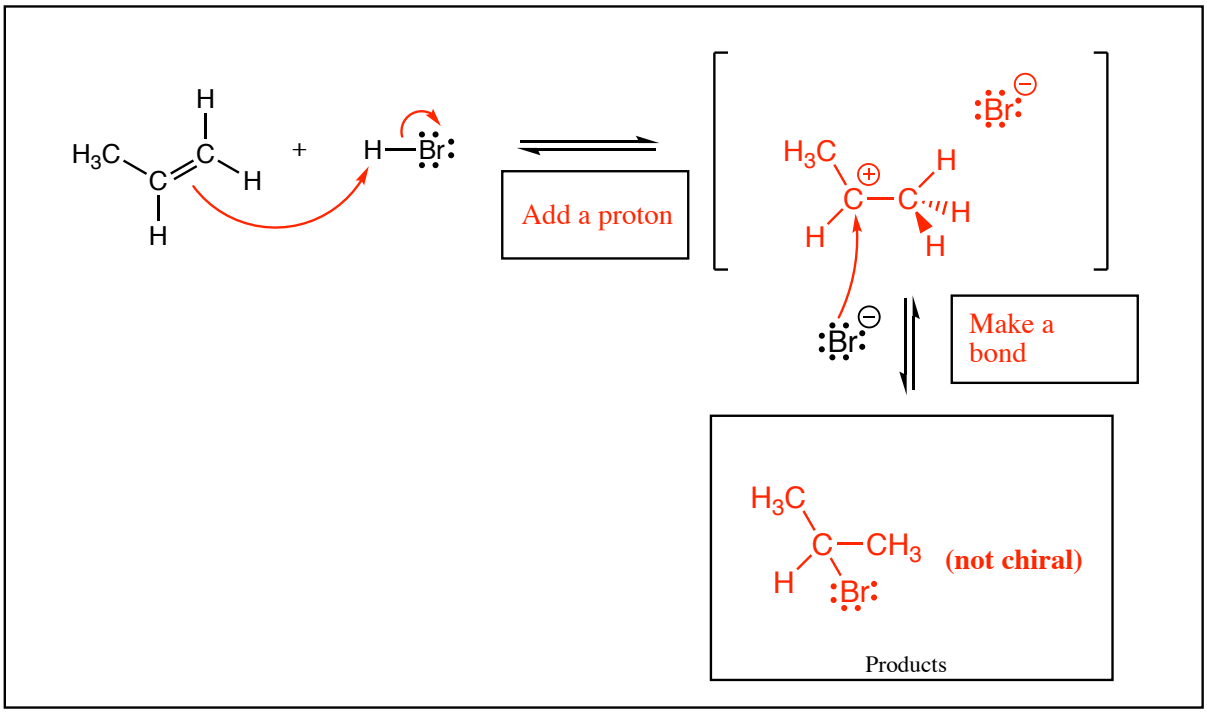
Meso

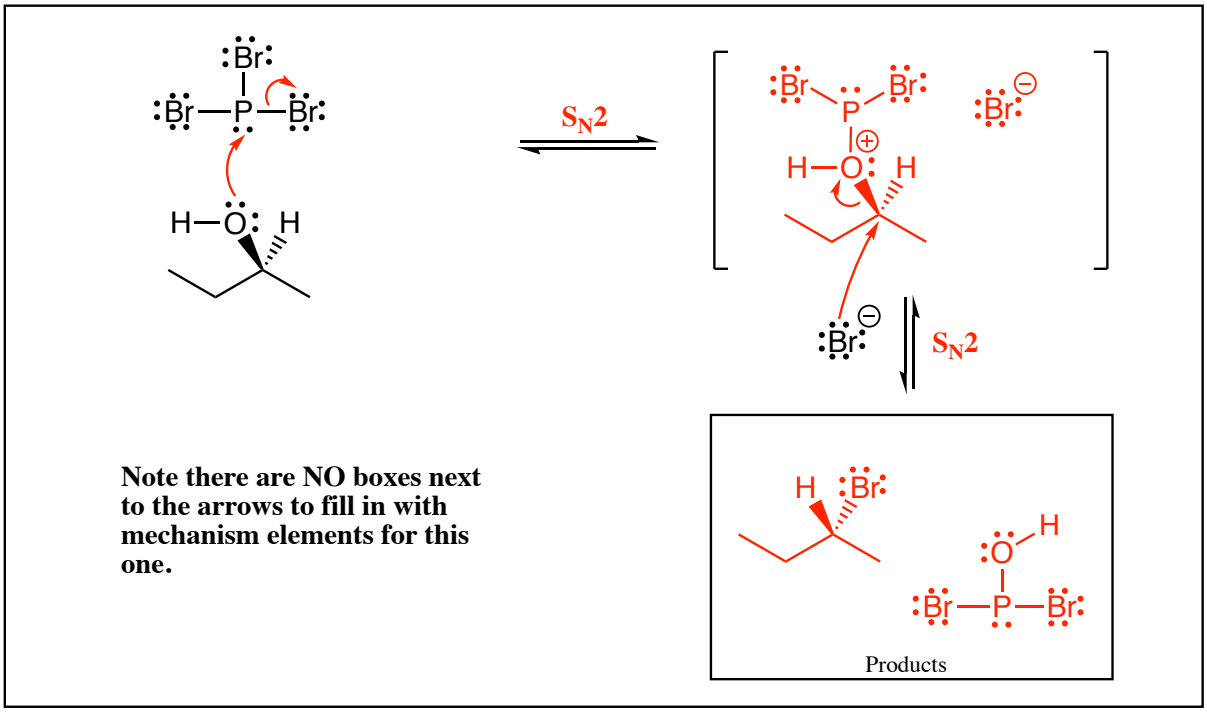




Diastereomers

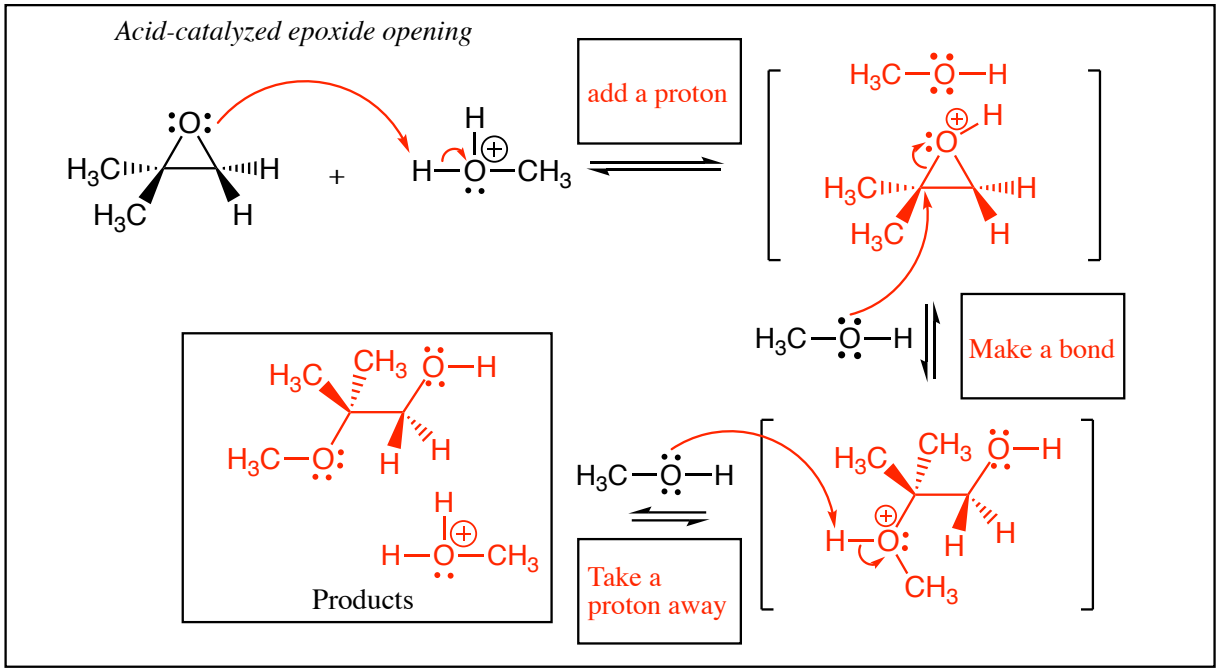
14. (20 pts.) Read these directions carefully. Read these directions carefully. (It was worth repeating) **For the following reactions, fill in the details of the mechanism. Draw the appropriate chemical structures and use an arrow to show how pairs of electrons are moved to** make and break bonds during the reaction. **For this question, you must draw all molecules produced in each step. Finally, fill in any boxes adjacent to the arrows with the type of step involved, such as "Make a bond" or "Take a proton away". Use wedges and dashes to indicate stereochemistry where appropriate.**



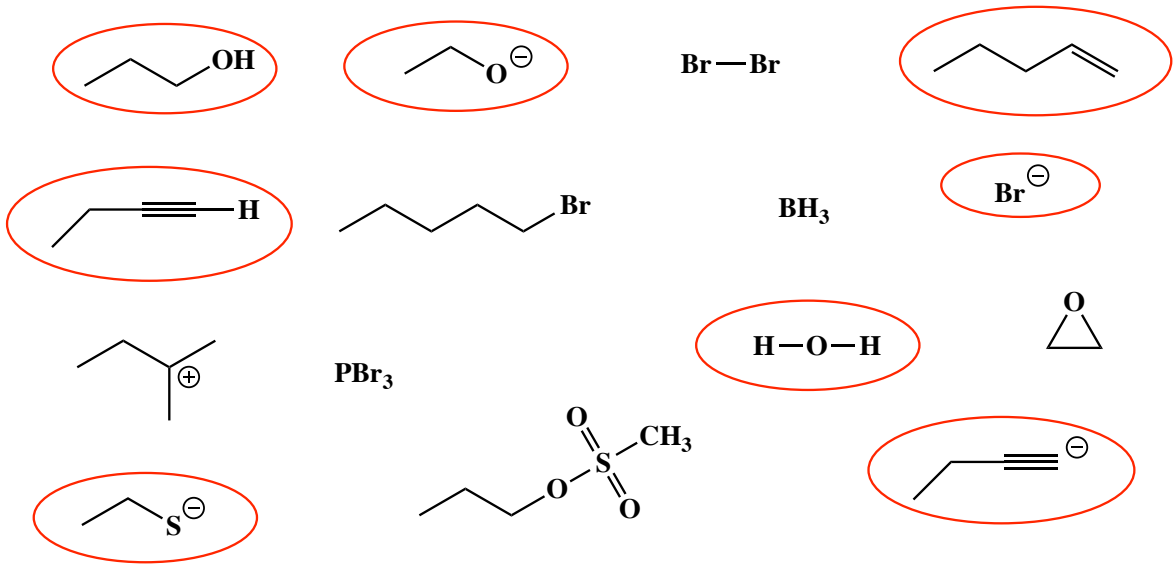


Note there are NO boxes next to the arrows to fill in with mechanism elements for this one.

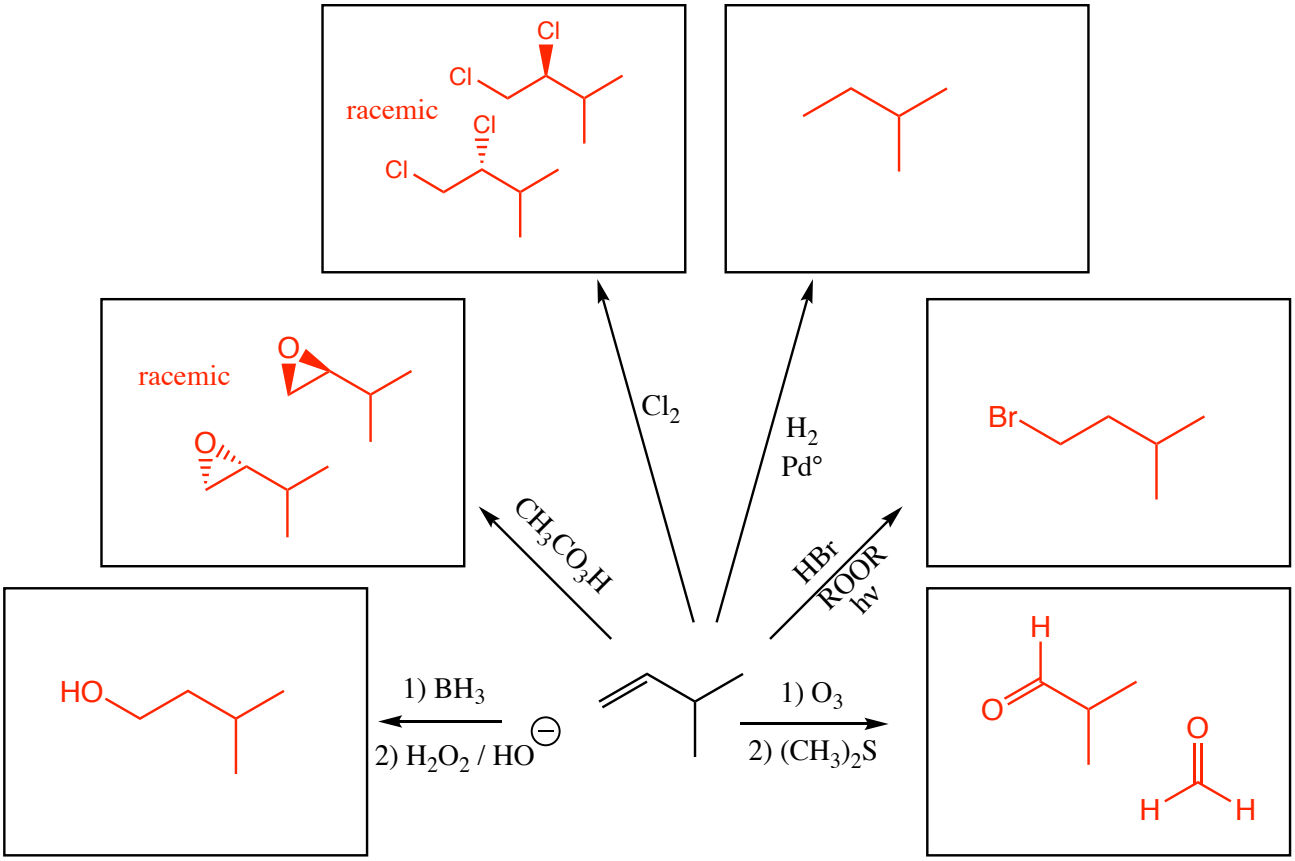
15. (17 pts.) Read these directions carefully. Read these directions carefully. (It was worth repeating) **For the following reactions, fill in the details of the mechanism. Draw the appropriate chemical structures and use an arrow to show how pairs of electrons are moved to** make and break bonds during the reaction. **For this question, you must draw all molecules produced in each step. Finally, fill in any boxes adjacent to the arrows with the type of step involved, such as "Make a bond" or "Take a proton away". Use wedges and dashes to indicate stereochemistry where appropriate.**

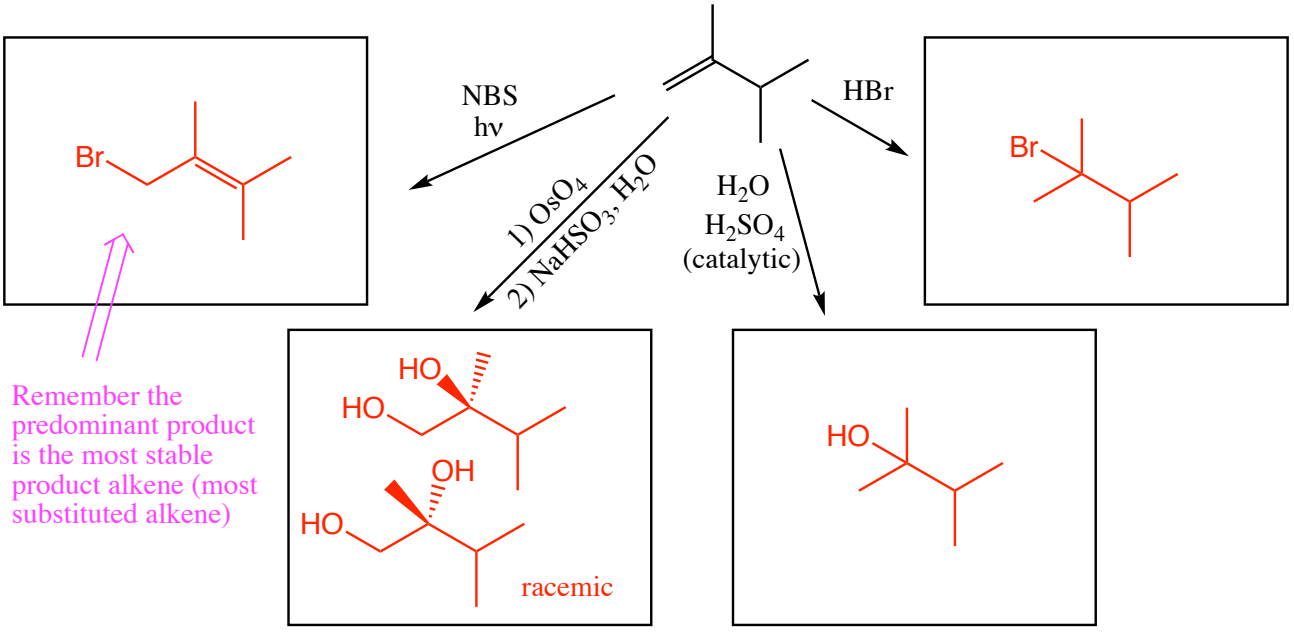


16. (15 pts) In order to predict mechanisms, it is important to understand the "personalities" of different reagents. Most important, it is essential that you can recognize **nucleophiles** and **electrophiles**. The following are either nucleophiles and electrophiles we have used in mechanisms this semester. **Draw a circle around each of the following molecules we have used as a nucleophile. Do not put any marks around the electrophiles.**



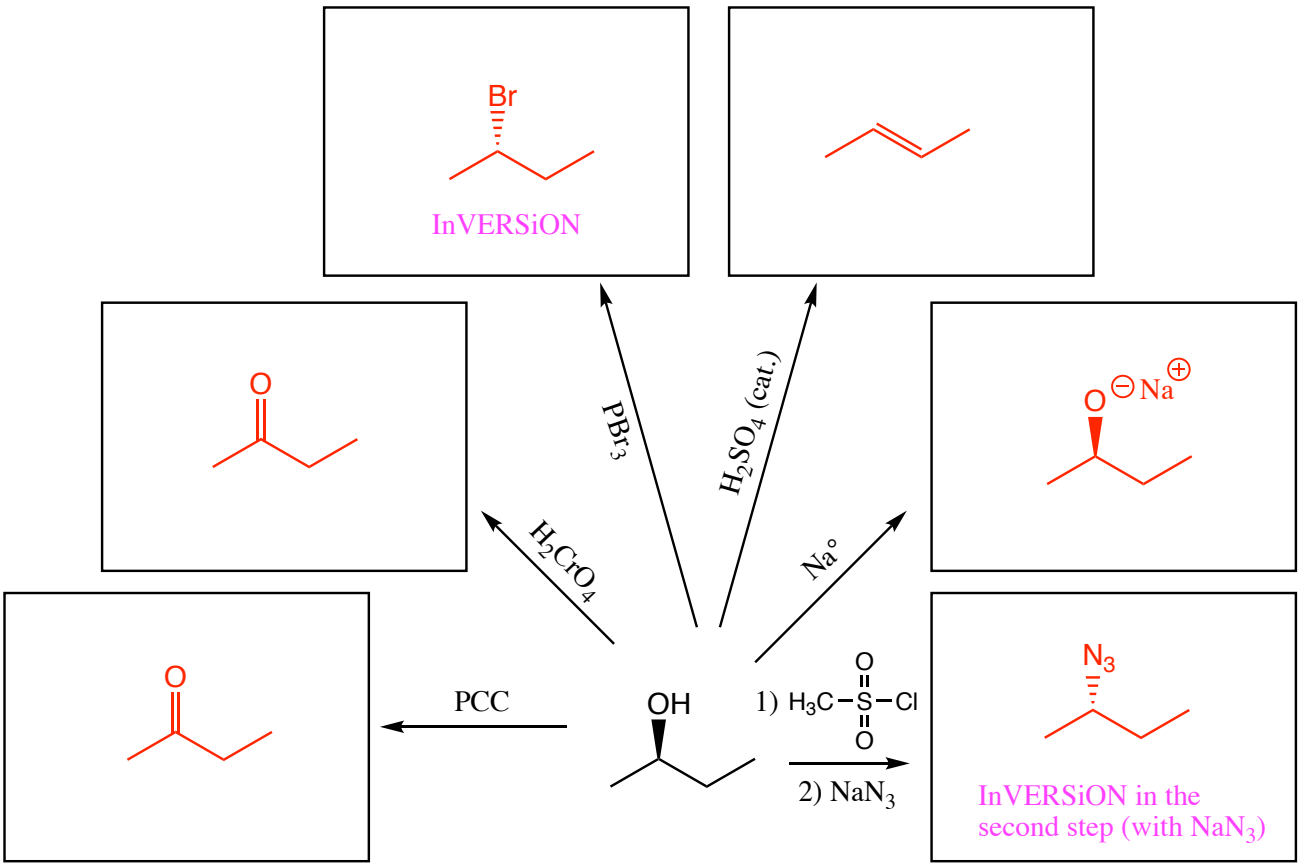
17. (3, 4 or 5 pts each) For the following, complete the reactions with the predominant carbon-containing product or products. You must indicate stereochemistry with wedges and dashes. You must draw all stereoisomers produced as predominant products and write "racemic" under the structures when appropriate. Assume no rearrangments take place.

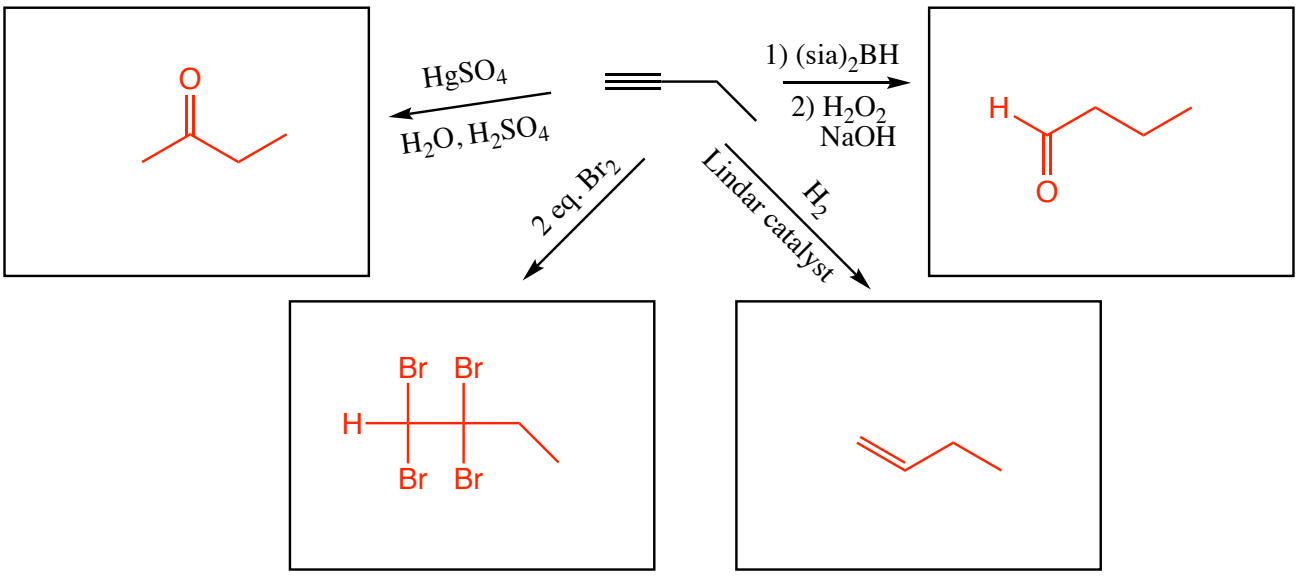




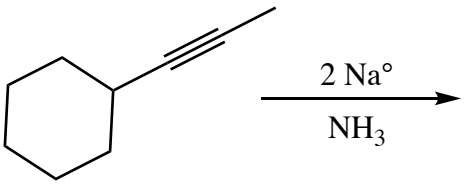
Remember the predominant product is the most stable product alkene (most substituted alkene)

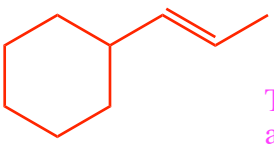
18. (3 or 5 pts each) For the following, complete the reactions with the predominant product or products. You must indicate stereochemistry with wedges and dashes. You must draw all stereoisomers produced as predominant products and write "racemic" under the structures when appropriate. Assume no rearrangments take place.



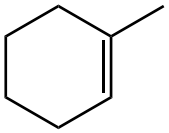


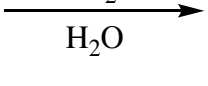
19. (3, 4 or 5 pts each) For the following, complete the reactions with the predominant product or products. You must indicate stereochemistry with wedges and dashes. You must draw all stereoisomers produced as predominant products and write "racemic" under the structures when appropriate. Assume no rearrangments take place.

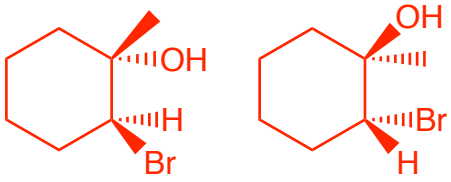




This reduction always gives the more stable (*E*) alkene as product

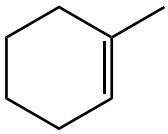


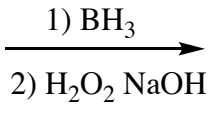


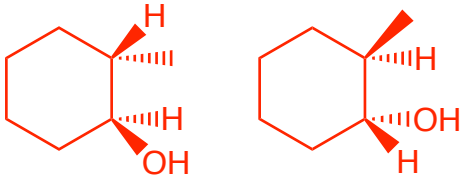


racemic

anti addition stereochemistry of OH and Br, OH adds to the more substituted C atom (Markovnikov)



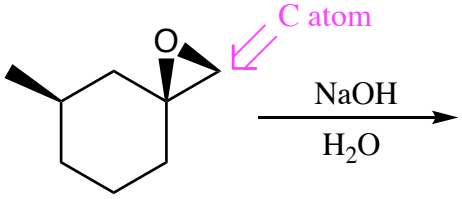


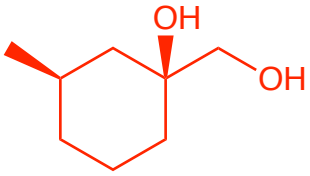


racemic

syn addition stereochemistry of the H and OH atoms, the OH ends up on the less substituted carbon (non-Markovnikov)

less hindered C atom



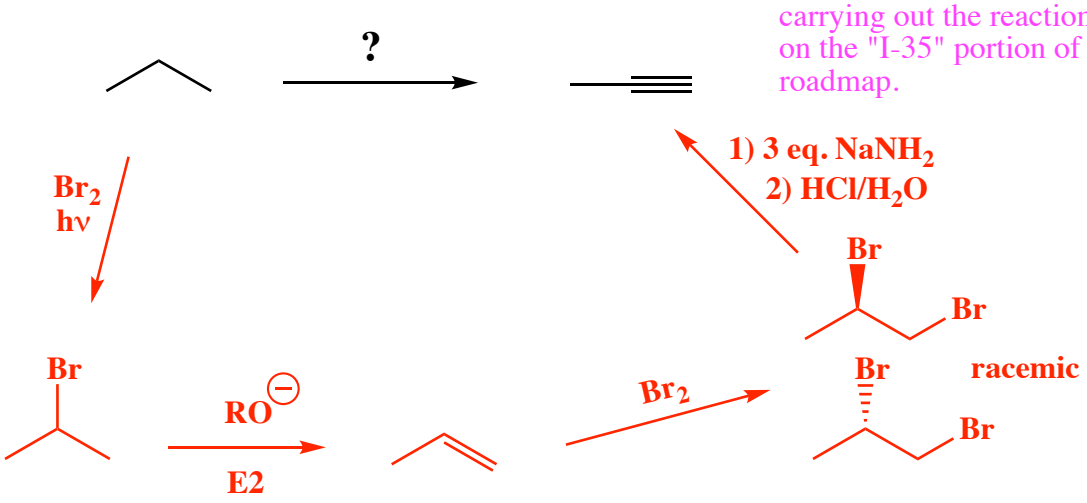


$HO^{\ominus}$ attacks the less hindered C atom of the epoxide, leaving the chiral center the same as it was in the starting material

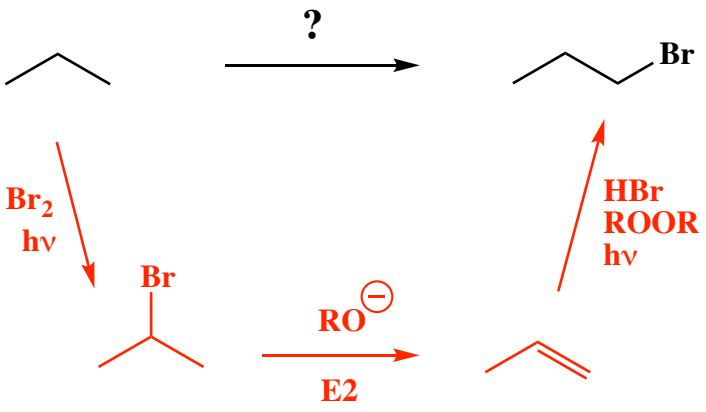
20. These are synthesis questions. You need to show how the starting material can be converted into the product(s) shown. You may use any reactions we have learned provided that the product(s) you draw for each step is/are the predominant one(s). Show all the reagents you need. Show each molecule synthesized along the way and be sure to pay attention to the regiochemistry and stereochemistry preferences for each reaction. You must draw all stereoisomers formed, and use wedges and dashes to indicate chirality at each chiral center. Write racemic when appropriate. **All the carbons of the product must come from carbons of the starting material.**

A) (10 pts)

Recognize that the product alkyne can be made from the starting alkane by carrying out the reactions on the "I-35" portion of the roadmap.



B) (7 pts)

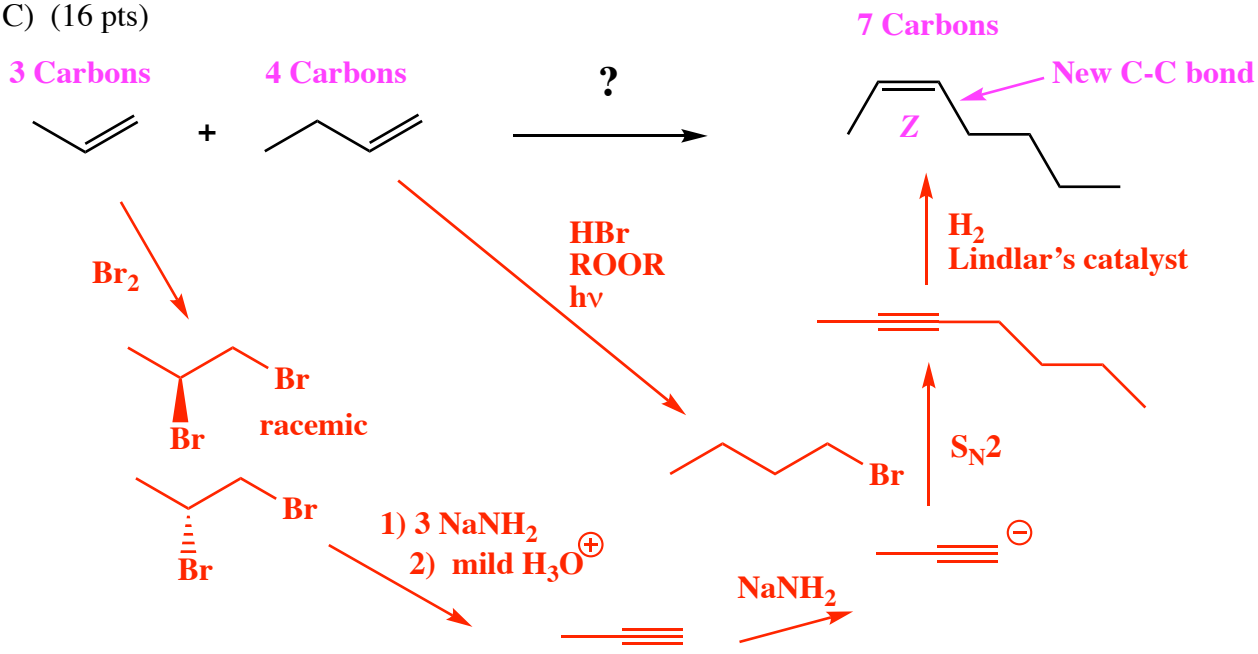


Recognize the product as NOT being the one made with a simple halogenation (that would be 2-bromopropane) **Recognize** this 1-bromopropane product as being derived from the non-Markovnikov addition of HBr to an alkene in the presence of peroxide, so make the alkene like above then carry out the non-Markovnikov reaction

20. (cont.) These are synthesis questions. You need to show how the starting material can be converted into the product(s) shown. You may use any reactions we have learned provided that the product(s) you draw for each step is/are the predominant one(s). Show all the reagents you need. Show each molecule synthesized along the way and be sure to pay attention to the regiochemistry and stereochemistry preferences for each reaction. You must draw all stereoisomers formed, and use wedges and dashes to indicate chirality at each chiral center. Write racemic when appropriate. **All the carbons of the product must come from carbons of the starting material.**

Recognize that a new C-C bond had to be made between the two starting material pieces so assume an alkyne anion needs to react with a haloakane somewhere in the synthesis. Also, **recognize** that this alkene is a Z alkene, the only reaction that can make Z alkene is H_2 reduction using Lindlar's catalyst so that must be the last step

C) (16 pts)

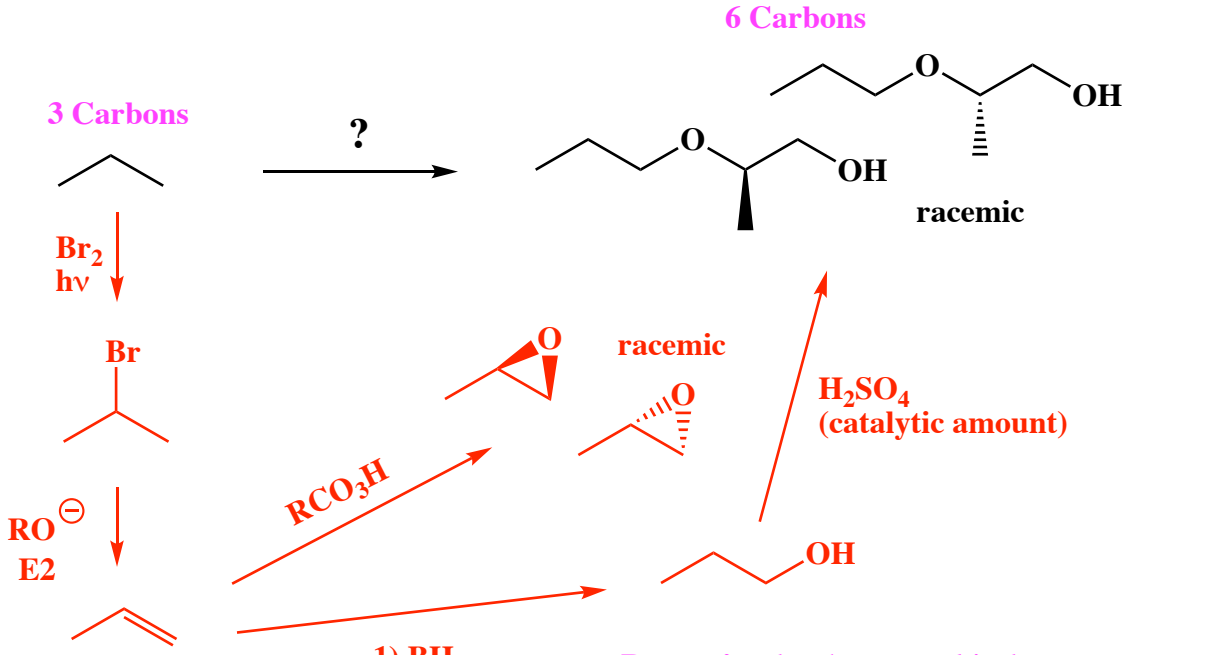


Recognize that to put the triple bond in the correct location in the product of this step, the three carbo piece must be the alkyne anion and the four carbo piece must be the haloalkane.

20. (cont.) These are synthesis questions. You need to show how the starting material can be converted into the product(s) shown. You may use any reactions we have learned provided that the product(s) you draw for each step is/are the predominant one(s). Show all the reagents you need. Show each molecule synthesized along the way and be sure to pay attention to the regiochemistry and stereochemistry preferences for each reaction. You must draw all stereoisomers formed, and use wedges and dashes to indicate chirality at each chiral center. Write racemic when appropriate. **All the carbons of the product must come from carbons of the starting material.**

Recognize the product as resulting from an epoxide reacting at the **more hindered central carbon** atom with 1-propanol, therefore it must be an acid-catalyzed epoxide reaction as the last step.

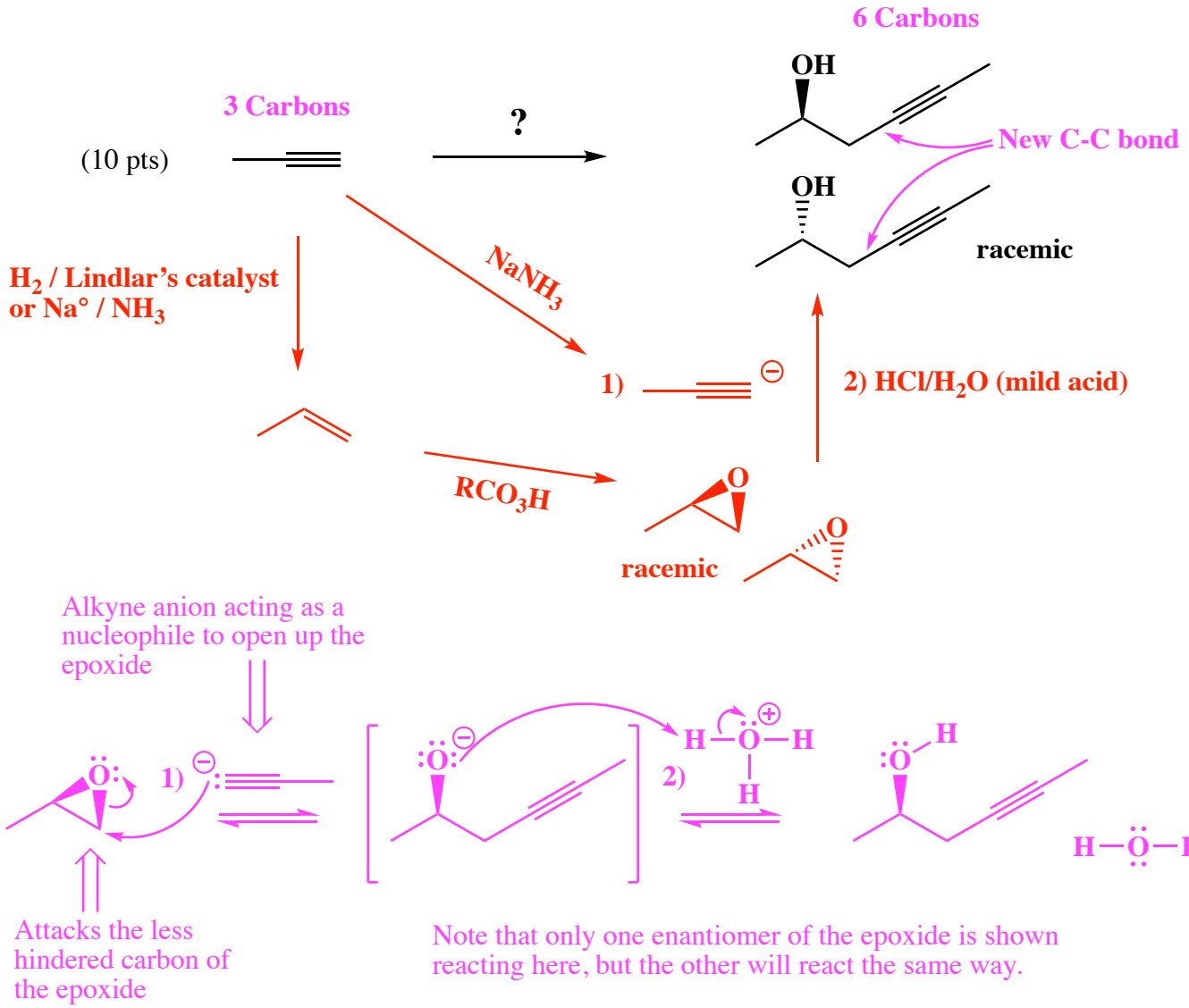
D (13 pts)



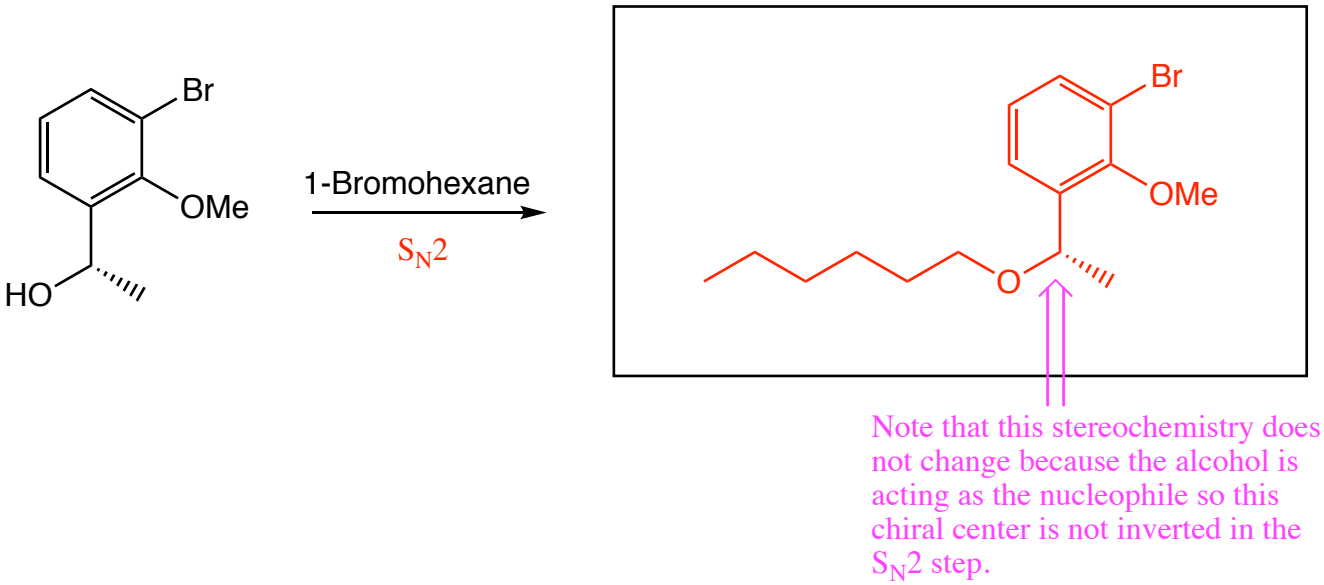
Recognize that 1-propanol is the non-Markovnikov addition product of the alkene so you need to use 1) BH_3 2)H_2O_2/NaOH, not simple hydration that would have given 2-propanol

21. Here is an "apply what you know" synthesis question. You have never seen the reaction that makes the final product, but you do know enough chemistry to figure out what happens. Think about what you know about the "personalities" of the different molecules we have seen, and you will be OK. Show all the reagents you need. Show each molecule synthesized along the way and be sure to pay attention to the regiochemistry and stereochemistry preferences for each reaction. You must draw all stereoisomers formed, and use wedges and dashes to indicate chirality at each chiral center. Write racemic when appropriate. **All the carbons of the product must come from carbons of the starting material.**

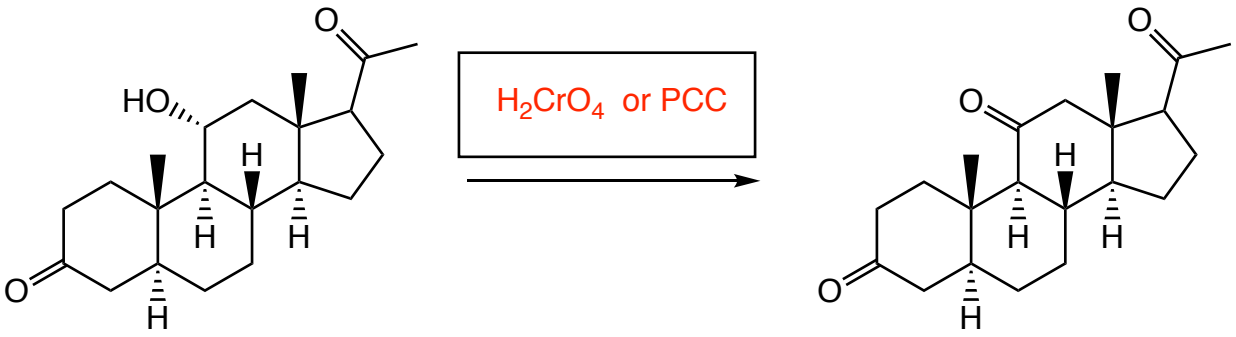
Recognize the product as having 6 carbons and the starting material has three. Therefore, there has to be a new C-C bond as shown. You have never seen this exact type of reaction before, but we wanted to you **recognize** the product as coming from an epoxide with an alkyne anion acting as a nucleophile. You have seen the alkyne anion reacting as a nucleophile with a primary haloalkane to make a new C-C bond before so this is not really an entirely new idea. Notice that as indicated below, alkyne anion will attack the less hindered carbon of the epoxide, explaining the regiochemistry of the product.



20. (8 pts) The chemistry you have learned this semester is used in the synthesis of important pharmaceuticals. Here are two examples. In the first, fill in the product in the space provided, in the next, fill in the reagent required to carry out the transformation indicated.



Note that this stereochemistry does not change because the alcohol is acting as the nucleophile so this chiral center is not inverted in the S_N2 step.



Have a great holiday break!!