NAME (Print): _____

SIGNATURE: _____

Chemistry 320M/328M
Dr. Brent Iverson
Final exam
December 15, 2012

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 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!!!

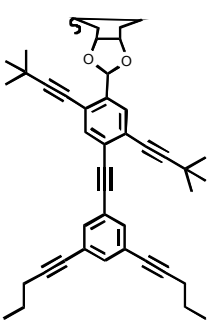
Page	Points	
1		(29)
2		(20)
3		(18)
4		(15)
5		(-)
6		(-)
7		(-)
8		(28)
9		(17)
10		(26)
11		(16)
12		(26)
13		(27)
14		(41)
15		(30)
16		(20)
17		(20)
18		(15)
19		(12)
20		(11)
21		(4)
22		(12)
Total		(387)

Honor Code

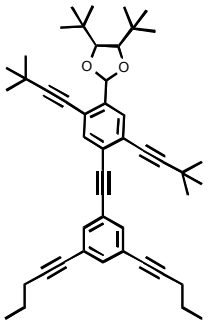
The core values of the University of Texas at Austin are learning, discovery, freedom, leadership, individual opportunity, and responsibility. Each member of the University is expected to uphold these values through integrity, honesty, trust, fairness, and respect toward peers and community.

_____

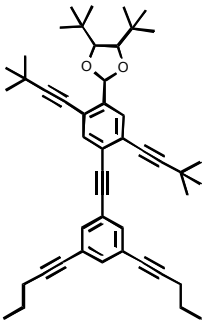
(Your signature)



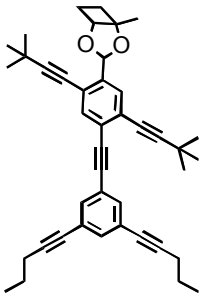
Dr. Iverson



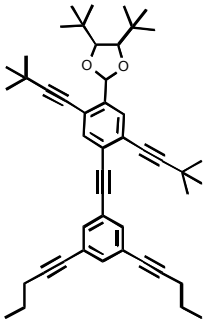
Amy



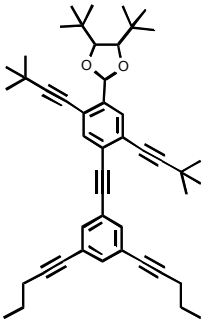
Mary



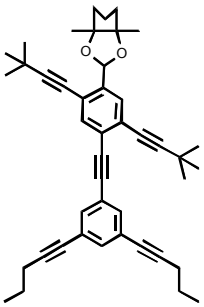
Cameron



Wenzong



Diana



Brian

The first semester of Organic Chemistry is a journey that begins with a review of material you have seen, transitions to the study of organic molecules, then settles in with a long discussion of reactions and their mechanisms. The pace accelerates through the chapters until we finish with the chemistry of epoxides. We finish with a chapter on NMR, the point of which is determing molecular structure. Solving organic synthesis problems requires not only a firm command of the many reactions and mechanisms we have presented, but also high level problem solving skills and a spark of creativity. You have all come a long way since late August when you first came to class. It is my sincere hope that this final serves to affirm that you have completed this journey successfully and caught the Organic Chemistry wave!

As you go through the test, use good test taking strategy by:

1) Remaining as relaxed and calm as possible
2) Working 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

Have a safe holiday and remember to exercise every chance you get.

If you stay in shape throughout your life, you will thank yourself more than you can imagine!!!

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:

1. Atoms prefer filled valence shells. 2. The most important question in chemistry is "Where are the electrons?" 3. Nature hates unpaired electrons. 4. Nature hates localized charges. 5. Most reactions involve nucleophiles (molecules with a location of particularly high electron density) attacking electrophiles (molecules with a location of particularly low electron density). 6. Steric interactions (atoms bumping into each other) can prevent reactions by keeping the reactive atoms away from each other. 7. Pi electrons prefer to be delocalized over as many adjacent sp^2 hybridized atoms (or sp^1 hybridized atoms in some cases) as possible, and aromaticity is the most stable form of pi electron delocalization.

PERIODIC TABLE OF THE ELEMENTS

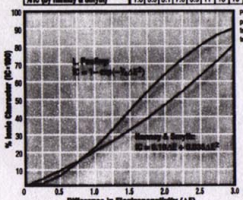
▼ Elementary Subatomic Particles

	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}	1.6749280(10) x 10^{-27}	0	= 0
Molar mass (kg/mol)	5.4857990(13) x 10^{-7}	1.0072764(12) x 10^{-3}	1.0086649(4) x 10^{-3}	0	= 0
Particle-electron mass ratio	1	1836.152701(37)	1838.683662(40)	0	= 0
Particle-proton mass ratio	5.446170(13) 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)	−1.7588196(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)	2.4263105(22) x 10^{-12}	1.3214002(12) x 10^{-15}	1.3195910(12) x 10^{-5}	–	–
Magnetic moment (J/T): μ	928.47701(31) x 10^{-26}	1.4106076(47) x 10^{-26}	0.9662376(40) x 10^{-26}	0	0
In Bohr magnetons: μ/μ_B	1.001159652193(10)	1.521032202(15) x 10^{-3}	1.04187563(25) x 10^{-3}	0	0
In nuclear magnetons: μ/μ_N	1836.282000(37)	2.792847386(63)	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	3.8	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	58	62	65	68	72	76	80	83	87



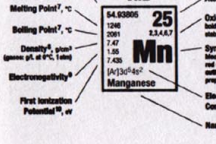
Percent ionic character describes the nature of a bond. Bonds possessing 50% or greater ionic character are commonly termed ionic; bonds with less than 50% ionic character are termed covalent. Pauling's equation was modified by Hanney & Smyth in order to achieve better agreement between experimental 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																		18 VIII O
1.00794 −259.34 −252.87 0.0899 2.20 13.598 $1s^1$	1 H Hydrogen	2 IIA IIA										13 IIIB IIIA	14 IVB IVA	15 VB VA	16 VIB VIA	17 VIIB VIIA	4.002602 −272.2 −268.93 0.1785 24.587 $1s^2$	2 He Helium
6.941 180.5 1342 0.534 0.98 5.392 $[He]2s^1$	3 Li Lithium	9.012182 1287 2471 1.8477 1.57 9.322 $[He]2s^2$	4 Be Beryllium									10.811 2075 4000 2.31 2.04 8.298 $[He]2s^22p^1$	5 B Boron	12.011 6492* 3825* 2.25 2.55 11.260 $[He]2s^22p^2$	6 C Carbon	14.00674 −210.00 −195.79 1.25046 3.04 14.534 $[He]2s^22p^3$	7 N Nitrogen	15.9994 −218.79 −182.95 1.429 3.44 13.618 $[He]2s^22p^4$	8 O Oxygen	18.9984032 −219.62 −188.12 1.69 3.98 17.422 $[He]2s^22p^5$	9 F Fluorine	20.1797 −248.59 −246.08 0.8002 – 21.564 $[He]2s^22p^6$	10 Ne Neon
22.989768 97.72 883 0.97 0.93 5.139 $[Ne]3s^1$	11 Na Sodium	24.3050 650 1090 1.74 1.31 7.646 $[Ne]3s^2$	12 Mg Magnesium	3 IIIA IIIB	4 IVA IVB	5 VA VB	6 VIA VIB	7 VIIA VIIB	8 VIIIA VIII	9 VIIIA VIII	10 VIIIA VIII	26.981539 660.32 2519 2.702 1.61 5.986 $[Ne]3s^23p^1$	13 Al Aluminum	28.0855 1414 3265* 2.33 1.90 8.151 $[Ne]3s^23p^2$	14 Si Silicon	30.973762 44.15 277 1.82 2.19 10.486 $[Ne]3s^23p^3$	15 P Phosphorus	32.066 −115.21 444.60 2.07 2.58 10.360 $[Ne]3s^23p^4$	16 S Sulfur	35.4527 −101.5 −34.04 3.214 3.16 12.967 $[Ne]3s^23p^5$	17 Cl Chlorine	39.948 −189.35 −185.85 1.784 – 15.759 $[Ne]3s^23p^6$	18 Ar Argon
39.0983 63.38 759 0.86 0.82 4.341 $[Ar]4s^1$	19 K Potassium	40.078 842 1484 1.54 1.00 6.113 $[Ar]4s^2$	20 Ca Calcium	44.955910 1541 2830 2.989 1.36 6.54 $[Ar]3d^14s^2$	21 Sc Scandium	47.88 1668 3287 4.5 1.54 6.82 $[Ar]3d^24s^2$	22 Ti Titanium	50.9415 1910 3407 5.96 1.63 6.74 $[Ar]3d^34s^2$	23 V Vanadium	51.9961 1907 2671 7.20 1.66 6.766 $[Ar]3d^54s^1$	24 Cr Chromium	54.93805 1246 2061 7.47 1.55 7.435 $[Ar]3d^54s^2$	25 Mn Manganese	55.847 1538 2861 7.86 1.83 7.870 $[Ar]3d^64s^2$	26 Fe Iron	58.93320 1495 2927 8.92 1.88 7.86 $[Ar]3d^74s^2$	27 Co Cobalt	58.6934 1455 2913 8.90 1.91 7.635 $[Ar]3d^84s^2$	28 Ni Nickel	63.546 1084.62 2562 8.94 1.90 7.726 $[Ar]3d^{10}4s^1$	29 Cu Copper	65.39 419.53 907 7.14 1.65 9.394 $[Ar]3d^{10}4s^2$	30 Zn Zinc	69.723 29.76 2204 5.904 1.81 5.999 $[Ar]3d^{10}4s^24p^1$	31 Ga Gallium	72.61 938.25 2833 5.35 2.01 7.899 $[Ar]3d^{10}4s^24p^2$	32 Ge Germanium	74.92159 817* 614* 5.727 2.18 9.81 $[Ar]3d^{10}4s^24p^3$	33 As Arsenic	78.96 221 685 4.81 2.55 9.752 $[Ar]3d^{10}4s^24p^4$	34 Se Selenium	79.904 −7.2 58.8 3.119 2.96 11.814 $[Ar]3d^{10}4s^24p^5$	35 Br Bromine	83.80 −157.36 −153.22 3.74 – 13.999 $[Ar]3d^{10}4s^24p^6$	36 Kr Krypton
85.4678 38.31 688 1.532 0.82 4.177 $[Kr]5s^1$	37 Rb Rubidium	87.62 777 1382 2.6 0.95 5.695 $[Kr]5s^2$	38 Sr Strontium	88.90585 1526 3336 4.469 1.22 6.38 $[Kr]4d^15s^2$	39 Y Yttrium	91.224 1855 4409 6.49 1.33 6.84 $[Kr]4d^25s^2$	40 Zr Zirconium	92.90638 2477 4744 8.57 1.6 6.9 $[Kr]4d^45s^1$	41 Nb Niobium	95.94 2623 4639 10.2 2.16 7.099 $[Kr]4d^55s^1$	42 Mo Molybdenum	(97.9072) 2157 4265 11.5 1.9 7.28 $[Kr]4d^55s^2$	43 Tc Technetium	101.07 2334 4156 12.3 2.2 7.37 $[Kr]4d^75s^1$	44 Ru Ruthenium	102.90550 1964 3695 12.4 2.28 7.46 $[Kr]4d^85s^1$	45 Rh Rhodium	106.42 1554.9 2963 12.02 2.20 8.34 $[Kr]4d^{10}$	46 Pd Palladium	107.8682 961.78 2162 10.5 1.93 7.576 $[Kr]4d^{10}5s^1$	47 Ag Silver	112.411 321.07 767 8.642 1.69 8.993 $[Kr]4d^{10}5s^2$	48 Cd Cadmium	114.818 156.60 2072 7.30 1.78 5.786 $[Kr]4d^{10}5s^25p^1$	49 In Indium	118.710 231.93 2602 7.28 1.96 7.344 $[Kr]4d^{10}5s^25p^2$	50 Sn Tin	121.757 630.63 1587 6.684 2.05 8.641 $[Kr]4d^{10}5s^25p^3$	51 Sb Antimony	127.60 449.51 988 6.25 2.1 9.009 $[Kr]4d^{10}5s^25p^4$	52 Te Tellurium	126.90447 113.7 184.4 4.93 2.66 10.451 $[Kr]4d^{10}5s^25p^5$	53 I Iodine	131.29 −111.75 −108.04 5.89 – 12.130 $[Kr]4d^{10}5s^25p^6$	54 Xe Xenon
132.90543 28.44 671 1.879 0.79 3.894 $[Xe]6s^1$	55 Cs Cesium	137.327 727 1897 3.594 0.89 5.212 $[Xe]6s^2$	56 Ba Barium	138.9055 920 3455 6.146 1.10 5.577 $[Xe]5d^16s^2$	57 La Lanthanum	178.49 2233 4603 13.31 1.3 7.0 $[Xe]4f^{14}5d^26s^2$	72 Hf Hafnium	180.9479 3017 5458 16.6 1.5 7.89 $[Xe]4f^{14}5d^36s^2$	73 Ta Tantalum	183.84 3422 5555 19.35 2.36 7.98 $[Xe]4f^{14}5d^46s^2$	74 W Tungsten	186.207 3186 5596 20.5 1.9 7.88 $[Xe]4f^{14}5d^56s^2$	75 Re Rhenium	190.23 3033 5012 22.61 2.2 8.7 $[Xe]4f^{14}5d^66s^2$	76 Os Osmium	192.22 2446 4428 22.65 2.20 9.1 $[Xe]4f^{14}5d^76s^2$	77 Ir Iridium	195.08 1768.4 3825 21.45 2.28 9.0 $[Xe]4f^{14}5d^96s^1$	78 Pt Platinum	196.96654 1064.18 2856 19.31 2.54 9.225 $[Xe]4f^{14}5d^{10}6s^1$	79 Au Gold	200.59 −38.83 356.73 13.546 2.00 10.437 $[Xe]4f^{14}5d^{10}6s^2$	80 Hg Mercury	204.3833 304 1473 11.85 2.04 6.108 $[Xe]4f^{14}5d^{10}6s^26p^1$	81 Tl Thallium	207.2 327.46 1749 11.34 2.33 7.416 $[Xe]4f^{14}5d^{10}6s^26p^2$	82 Pb Lead	208.98037 271.40 1564 9.78 2.02 7.289 $[Xe]4f^{14}5d^{10}6s^26p^3$	83 Bi Bismuth	(208.9824) 254 962 9.196 2.0 8.42 $[Xe]4f^{14}5d^{10}6s^26p^4$	84 Po Polonium	(209.9871) 302 337 – 2.2 – $[Xe]4f^{14}5d^{10}6s^26p^5$	85 At Astatine	(222.0176) −71 −61.7 9.73 – 10.748 $[Xe]4f^{14}5d^{10}6s^26p^6$	86 Rn Radon
(223.0197) 27 677 1 – 0.7 – $[Rn]7s^1$	87 Fr Francium	(226.0254) 700 <1140 5.0 1.1 5.279 $[Rn]7s^2$	88 Ra Radium	(227.0278) 1061 2198 10.07 1.1 6.5 $[Rn]6d^17s^2$	89 ** Ac Actinium	(261.11) – – – – – $[Rn]5f^{14}6d^37s^2$	104 Unq Unnilquadium	(262.114) – – – – – $[Rn]5f^{14}6d^47s^2$	105 Unp Unnilpentium	(263.118) – – – – – $[Rn]5f^{14}6d^57s^2$	106 Unh Unnilhexium	(262.12) – – – – – $[Rn]5f^{14}6d^67s^2$	107 Uns Unnilseptium	(265) – – – – – $[Rn]5f^{14}6d^77s^2$	108 Uno Unniloctium	(266) – – – – – $[Rn]5f^{14}6d^87s^2$	109 Une Unnilennium	(272) – – – – – $[Rn]5f^{14}6d^97s^2$	110 Uun Ununnium																		

The data for this reference guide were obtained from the latest scientific and government sources (IUPAC, CODATA, National Bureau of Standards, etc.). Estimated 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. Rowed 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 charge 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 older group classifications systems still in use today rely on an A/B coding scheme to categorize periodic properties. Because of the potential for confusion between these two systems (i.e., IVA 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 $[Xe]4f^15d^16s^2$	58 Ce Cerium	140.90765 931 3510 6.773 1.13 5.422 $[Xe]4f^36s^2$	59 Pr Praseodymium	144.24 1016 3068 7.00 1.14 5.489 $[Xe]4f^46s^2$	60 Nd Neodymium	(144.9127) 1042 3000 7.264 1.13 5.554 $[Xe]4f^56s^2$	61 Pm Promethium	150.36 1072 1794 7.536 1.17 5.631 $[Xe]4f^66s^2$	62 Sm Samarium	151.965 822 1596 5.244 1.2 5.666 $[Xe]4f^76s^2$	63 Eu Europium	157.25 1314 3264 7.901 1.20 6.141 $[Xe]4f^75d^16s^2$	64 Gd Gadolinium	158.92534 1359 3231 8.230 1.2 5.842 $[Xe]4f^96s^2$	65 Tb Terbium	162.50 1411 2567 8.551 1.22 5.927 $[Xe]4f^{10}6s^2$	66 Dy Dysprosium	164.93032 1472 2694 8.80 1.23 6.015 $[Xe]4f^{11}6s^2$	67 Ho Holmium	167.26 1529 2802 9.066 1.24 6.101 $[Xe]4f^{12}6s^2$	68 Er Erbium	168.93421 1545 1946 9.321 1.25 6.18436 $[Xe]4f^{13}6s^2$	69 Tm Thulium	173.04 824 1194 6.966 – 6.25394 $[Xe]4f^{14}6s^2$	70 Yb Ytterbium	174.967 1663 3393 9.84 1.27 5.42589 $[Xe]4f^{14}5d^16s^2$	71 Lu Lutetium
●●	232.0381 1750 4788 11.72 1.3 6.08 $[Rn]6d^27s^2$	90 Th Thorium	231.03588 1572 – 15.37 1.5 5.89 $[Rn]5f^26d^17s^2$	91 Pa Protactinium	238.0289 1135 4131 19.05 ±0.02 1.38 1.7 6.19 $[Rn]5f^36d^17s^2$	92 U Uranium	(237.0482) 644 3902 20.45 1.36 6.19 $[Rn]5f^46d^17s^2$	93 Np Neptunium	(244.0642) 640 3235 19.816 1.28 6.06 $[Rn]5f^67s^2$	94 Pu Plutonium	(243.0614) 1176 3013 13.67 1.3 5.993 $[Rn]5f^77s^2$	95 Am Americium	(247.0703) 1345 – 13.51 1.3 6.02 $[Rn]5f^76d^17s^2$	96 Cm Curium	(247.0703) 1050 – 14.78 1.3 6.23 $[Rn]5f^97s^2$	97 Bk Berkelium	(251.0796) 900 – – 1.3 6.30 $[Rn]5f^{10}7s^2$	98 Cf Californium	(252.083) 900 – – 1.3 6.42 $[Rn]5f^{11}7s^2$	99 Es Einsteinium	(257.0951) 1527 – – 1.3 6.50 $[Rn]5f^{12}7s^2$	100 Fm Fermium	(258.10) 827 – – 1.3 6.58 $[Rn]5f^{13}7s^2$	101 Md Mendelevium	(259.1009) 827 – – 1.3 6.65 $[Rn]5f^{14}7s^2$	102 No Nobelium	(262.11) 1627 – – – – $[Rn]5f^{14}6d^17s^2$	103 Lr Lawrencium

PAPERTECH

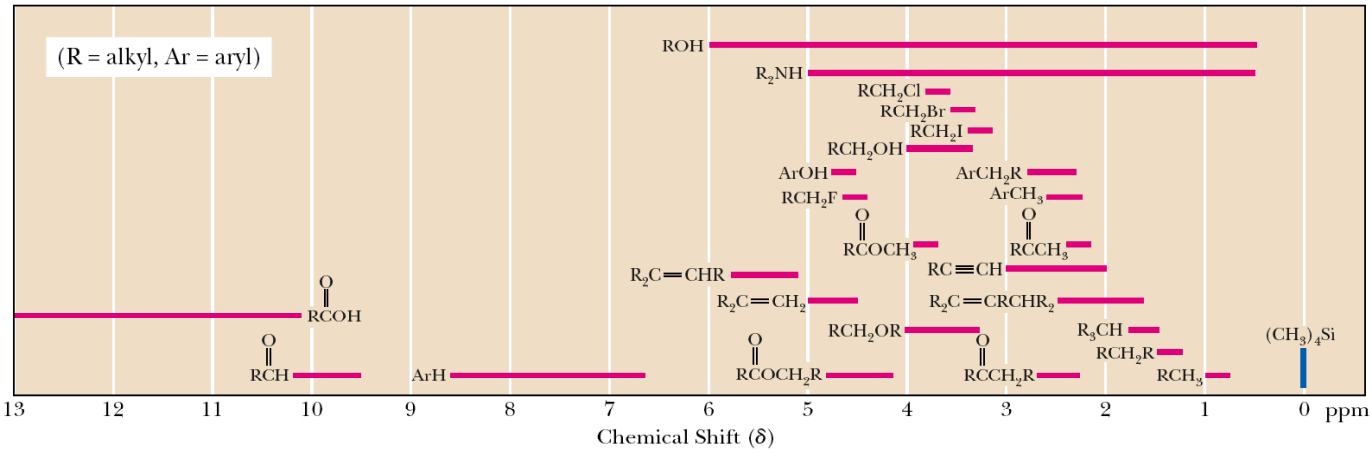
Editors: T. K. Varga, M.A.Sc. & C. Bello, M.A.Sc.

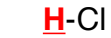
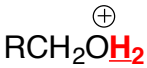
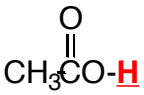
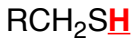
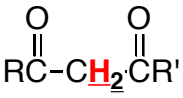
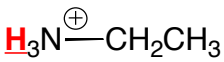
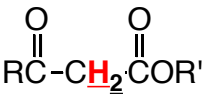
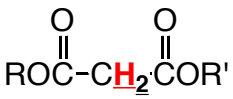
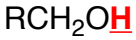
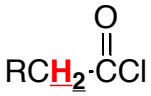
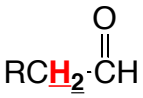
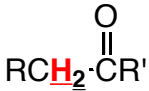
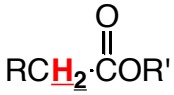
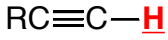
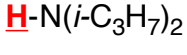
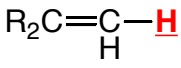
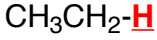
Product No. LCH-04F

ISBN 1-55080-073-6

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.



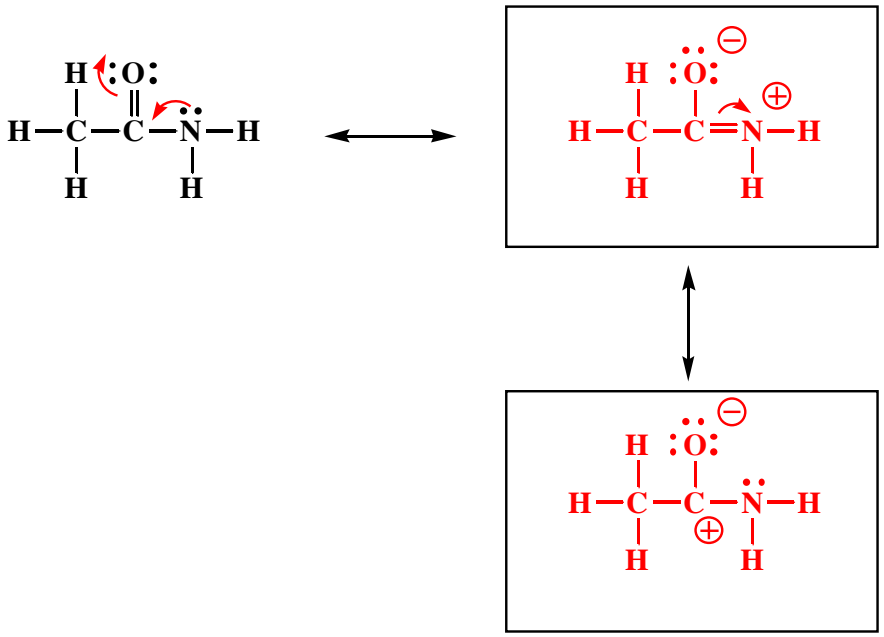
Compound		pK_a
Hydrochloric acid		-7
Protonated alcohol		-2
Hydronium ion		-1.7
Acetic acid		4.8
Ammonium ion		9.2
Thiols		10-12
β-Dicarbonyls		10
Ethyl ammonium ion		10.8
β-Ketoesters		11
β-Diesters		13
Water		15.7
Alcohols		15-19
Acid chlorides		16
Aldehydes		18-20
Ketones		18-20
Esters		23-25
Terminal 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?

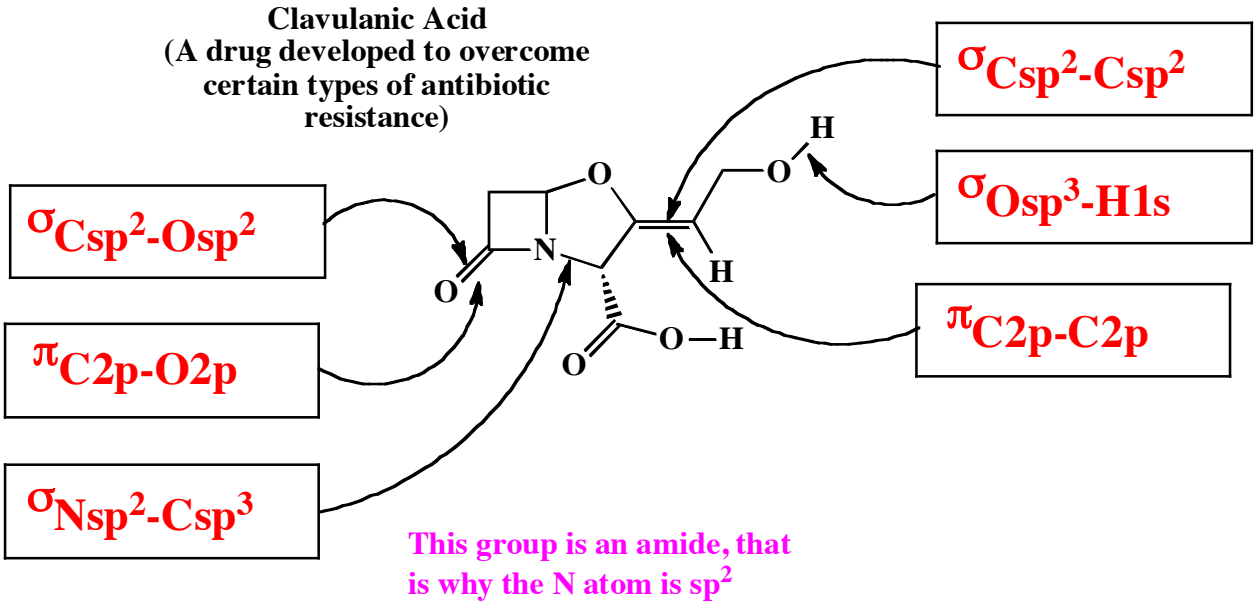
2. (10 pts) Amides are best represented as the hybrid of three contributing structures. Draw the second and third important contributing structures in the spaces provided, including all lone pairs and formal charges. For the two structures on the left in each problem, use arrows to indicate the movement 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



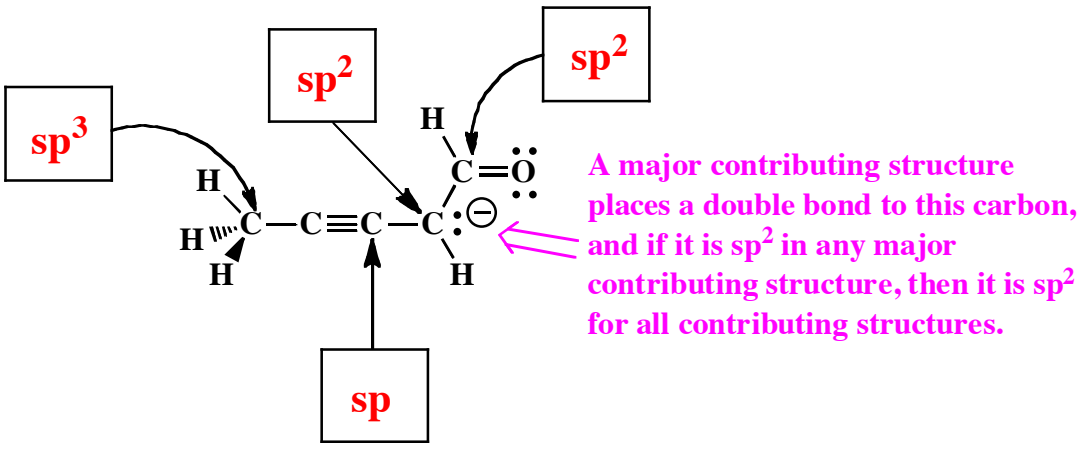
3. (14 points) Suppose a relative of yours is having an MRI. In no more than four sentences, explain to them what is happening when they have the MRI scan. We will be looking for a minumum of 7 key points here and your ansswer should match a recent Rule of the Day.

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 protons** 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 protons**, **especially the protons 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: $\sigma_{Csp^3\text{-}H1s}$



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



6. (1 pt each) **Circle all the True statements.** (Do not circle any false statements) 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.

A. More electronegative atoms attract the majority of electron density in a bond, thereby answering the most important question in chemistry.

B. A sigma bond has the majority of electron density above and below the bond axis, while a pi bond has the majority of electron density between atomic nuclei.

C. Constitutional isomers are molecules with the same molecular formula, but have the atoms connected differently.

D. The preferred staggered conformations of butane are the "gauche" conformations, rather than the "anti" conformation.

E. Stereoisomers have the same connectivity (they are the same constitutional isomer), but the atoms are arranged differently in space.

F. Dispersion forces are proportional to surface area , so the smaller the surface area of an alkane, the greater the attraction between molecules and the higher the boiling point.

G. Substituted cyclohexanes prefer to have as many substituents axial as possible, with the larger substituents dominating.

H. *Trans* alkenes are more stable than cis alkenes because *cis* alkenes have some non-bonded interaction strain.

I. The enol form of a compound rapidly tautomerizes to the more stable keto form.

J. The keto form of a compound rapidly tautomerizes to the more stable enol form.

K. The keto form of a compound rapidly mesmerizes to the more stable enol form.

L. In organic synthesis, A KEY PARADIGM is the that functional groups (OH group, Pi bond of an alkene, etc.) react the same in large complex molecules as they do in simple structures.

M. Ethers can be synthesized using an S_N2 reaction between a primary alkyl halide and an alkoxide (called the Williamson ether synthesis)

N. Ethers are synthesized using an S_N1 reaction between a tertiary alkyl halide and an alkoxide (called the Williamson County ether synthesis)

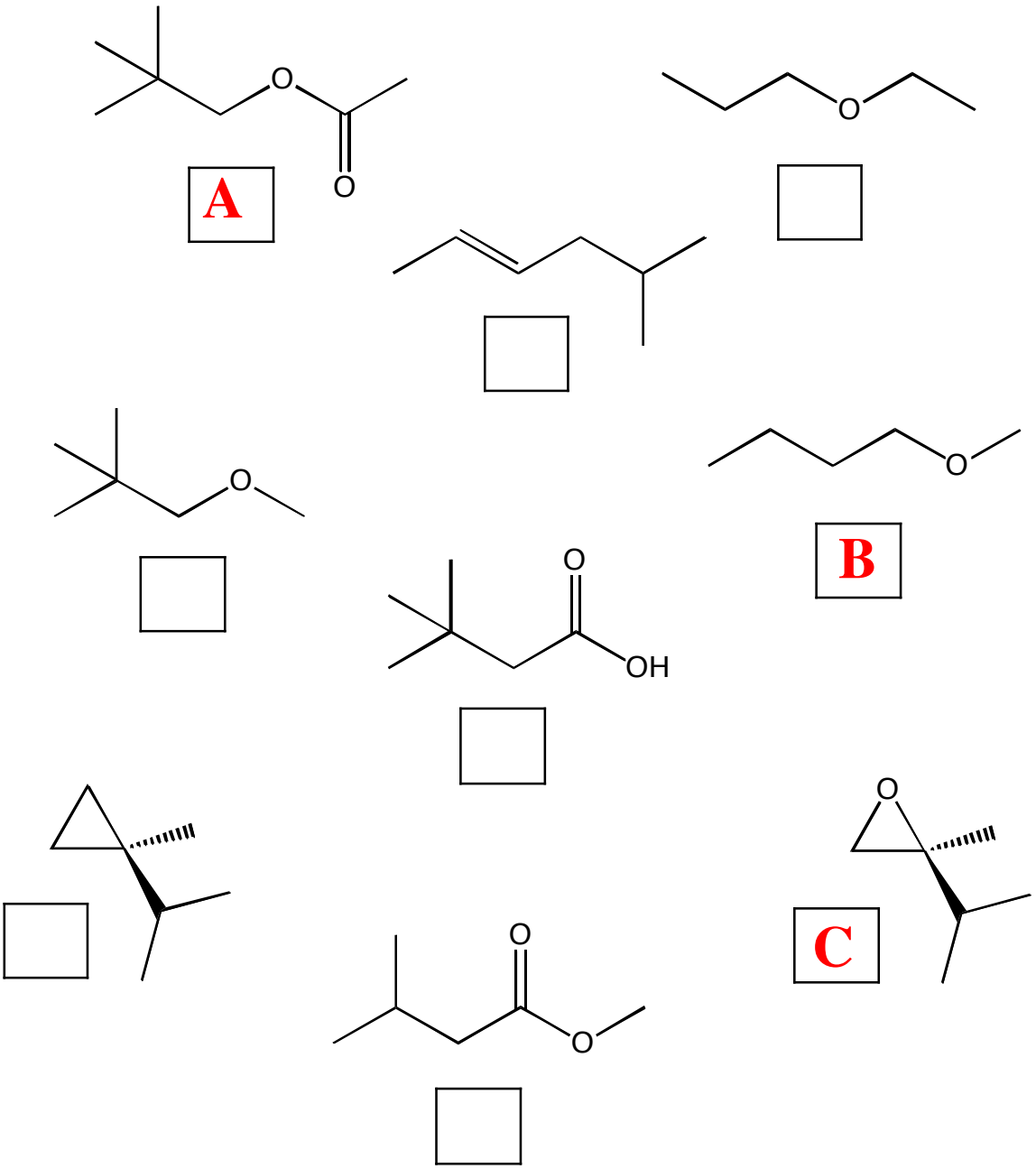
O. Epoxides are important because the ring strain within epoxides allows them to react with nucleophiles.

P. A ^1H nucleus surrounded by greater electron density is considered to be more shielded and comes into resonance (absorbs electromgnetic radiation) at a lower frequency (smaller ppm).

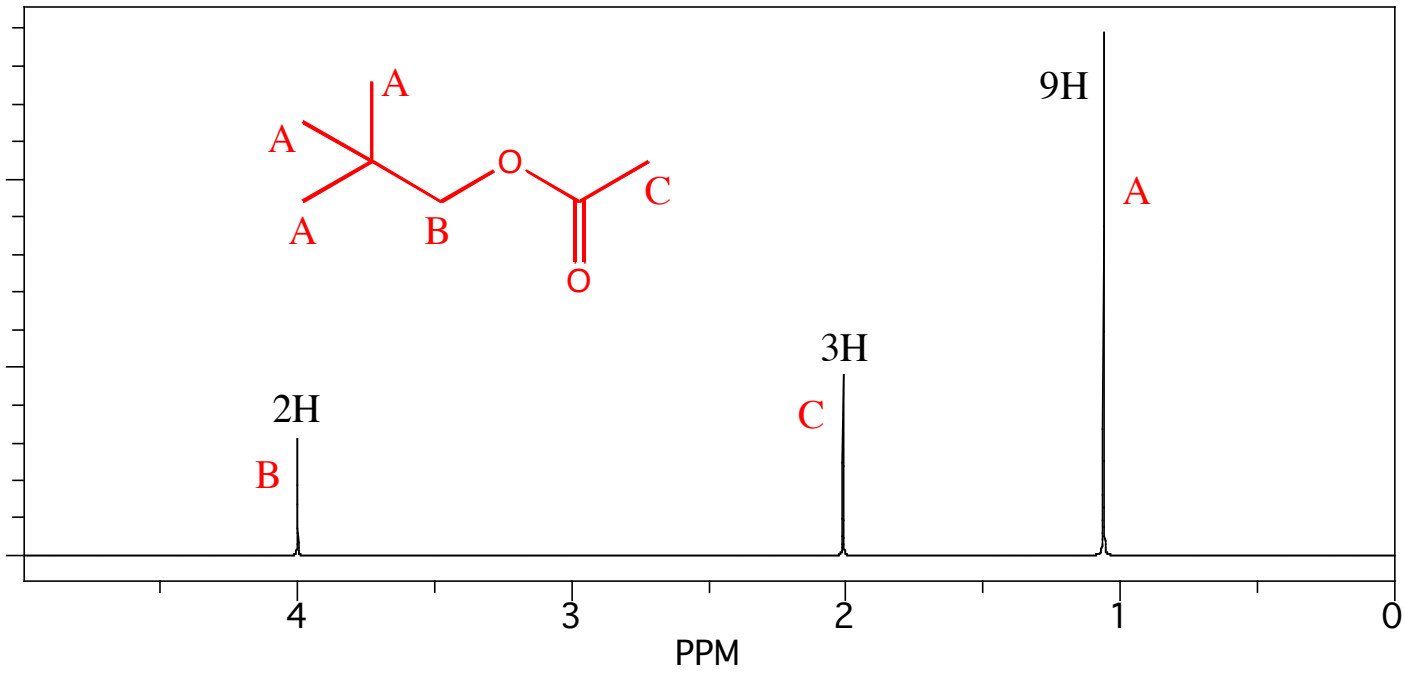
Q. "Resonance" in NMR refers to the phenomenon of absorption of energy when a nuclear spin "flips".

R. 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!

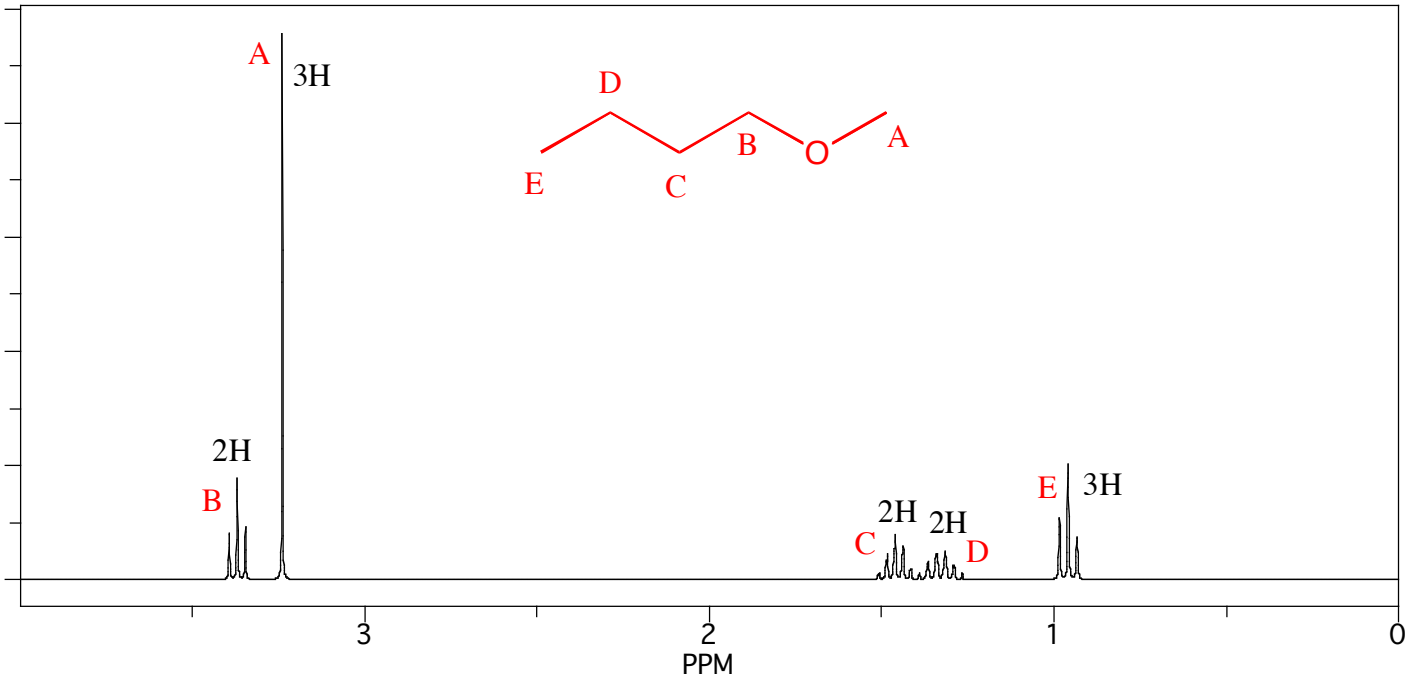
8. (15 pts total) On the following three pages there are NMR spectra. The relative integrations are given above each signal. Assign each spectra to the appropriate structure out of the following possibilities. Each NMR spectrum has a letter on it. **Write the appropriate letter underneath the molecules in the space provided.** Notice that not all of the molecules below will have letters underneath them, as there are only three spectra but seven molecules.



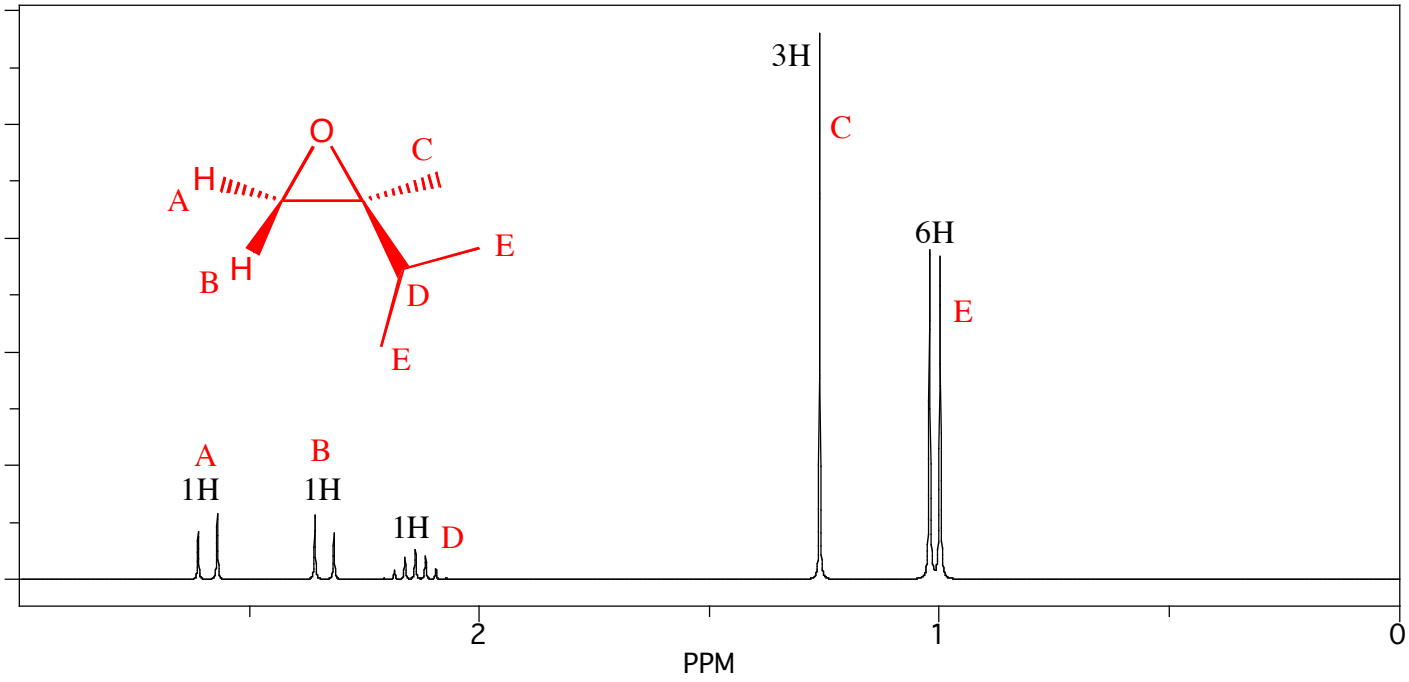
A



B

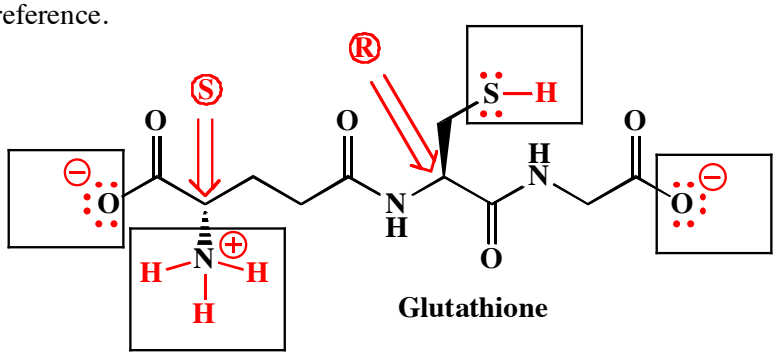


C



9. The following molecule is called glutathione. It is found in high concentration in living cells where it helps maintain the proper oxidation potential as well as providing protection from oxidants such as free radicals. **In the boxes, fill in the proper number of bonds to H atoms, lone pairs, and formal charges to show the protonation state of glutathione at pH 7.0.** Use the pK_a table provided at the beginning of the test for reference.

A.(8 pts)



Glutathione

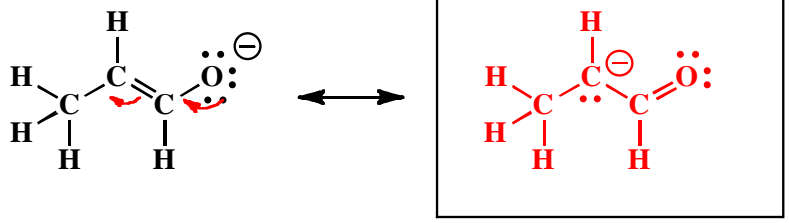
B. (1 pt) **What is the total charge on glutathione at pH 7.0?** **-1**

C. (1 pt) **How many chiral centers does glutathione have?** **2**

D. (2 pt) **Glutathione is found as the single stereoisomer shown. Write an "R" or "S" next to each chiral center on the structure above.**

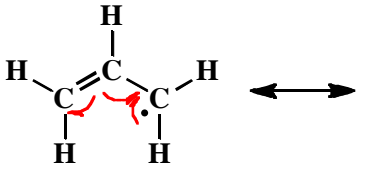
10. (16 pts total) The following are contributing structures for important resonance hybrids. Draw the other important resonance contributing structure in the box provided. Draw arrows on the structures on the left that indicate the flow of electrons that produce the contributing structures you drew to the right. Be sure to show all lone pairs and formal charges.

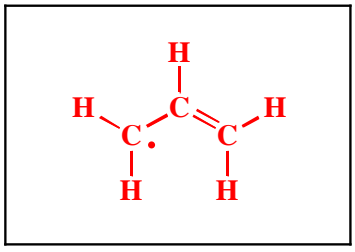
A.



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

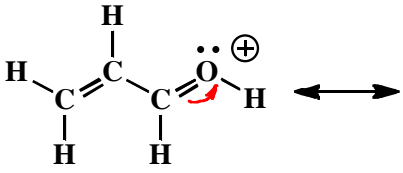
B.

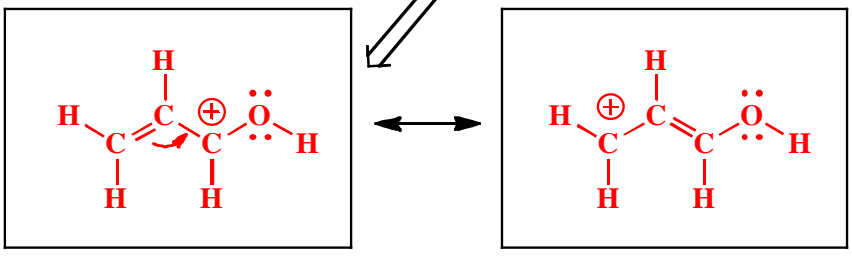




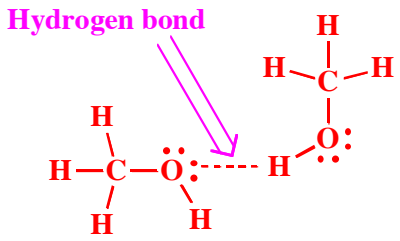
Yes, put arrow(s) on this structure to show how it is transformed to the structure to the far right!

C.



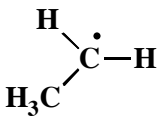


11. (5 pts) A hydrogen bond is the strongest interaction seen among neutral molecules. **In the space provided, draw two molecules of methanol (CH_3OH) and show a hydrogen bond between them. Use a dashed line (-----) to indicate the hydrogen bond. Show all lone pairs.**

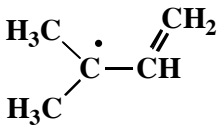


12. (12 pts. total) Rank the following species in terms of the stated property from 1 to 4 with intermediate numbers to rank the species of intermediate stability activity. **Please make sure you know what we want, as you will get no credit if you get the numbers backwards!**

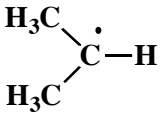
Radical Stability: Place a **1** under the most stable radical and a **4** under the least stable radical.



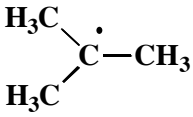
4



1

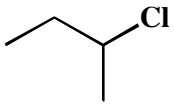


3

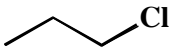


2

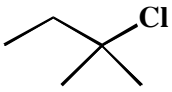
Reaction with nucleophiles: Place a **1** under the molecule that is most reactive in an S_N2 reaction and a **4** under the molecule that is least reactive in an S_N2 reaction.



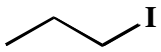
3



2

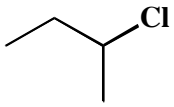


4

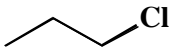


1

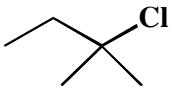
Reaction in an S_N1/E1 reaction: Place a **1** under the molecule that is most reactive in an S_N1/E1 reaction and a **4** under the molecule that is least reactive in an S_N1/E1 reaction.



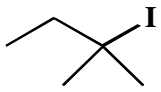
3



4



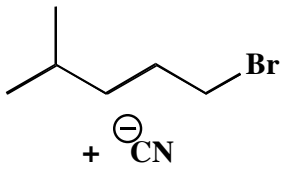
2



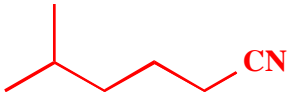
1

13. (5, 6 or 8 pts each) The following reactions all involve chemistry of alkyl halides. **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).

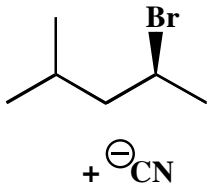
A.



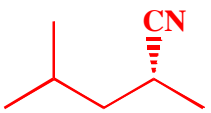
S_N2



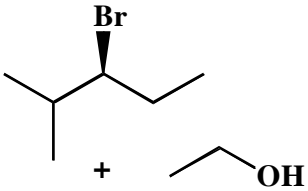
B.



S_N2

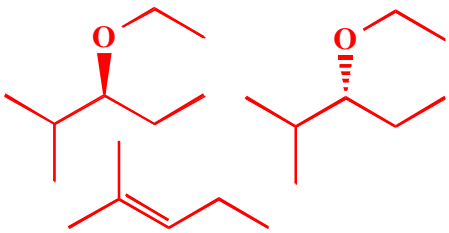


C.



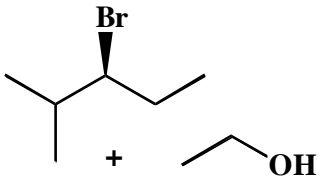
S_N1 / E1

(asssume no rearrangement)



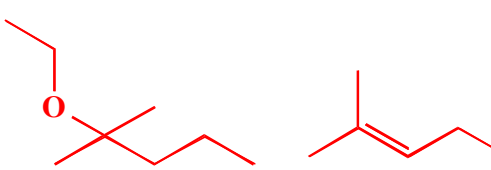
Repeat the last one, but only draw rearranged products

D.



S_N1 / E1

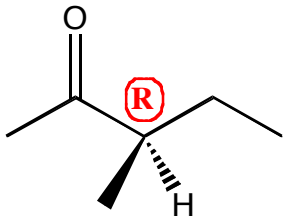
(asssume rearrangement)

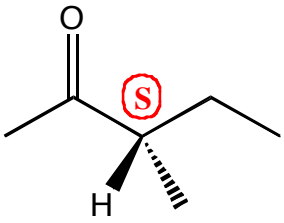


(2 pts) **For the reagents listed in parts C and D, how many total *different* products will be made if the reaction proceeds both with and without rearrangment?**

4

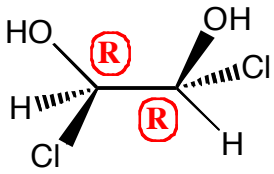
14. (8 pts total) On the line provided, state the stereochemical relationship between each pair of molecules: **enantiomers, diastereomers, or the same molecule**. I recommend you assign R and S to each chiral center to help answer this question. **Circle all meso compounds.**

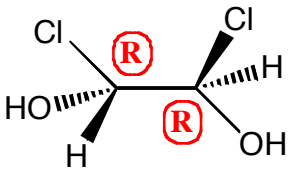




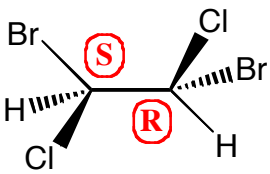
Relationship

Enantiomers

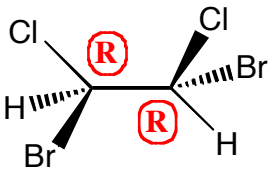




Same Molecule

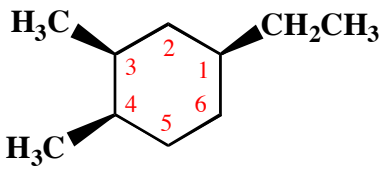


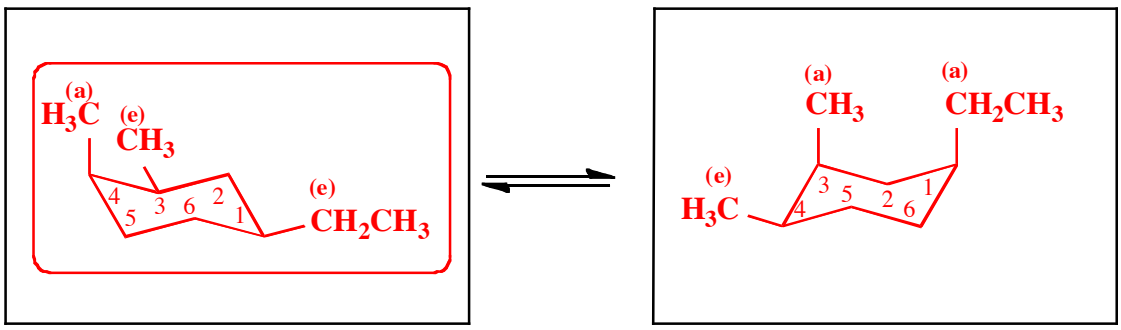
Meso



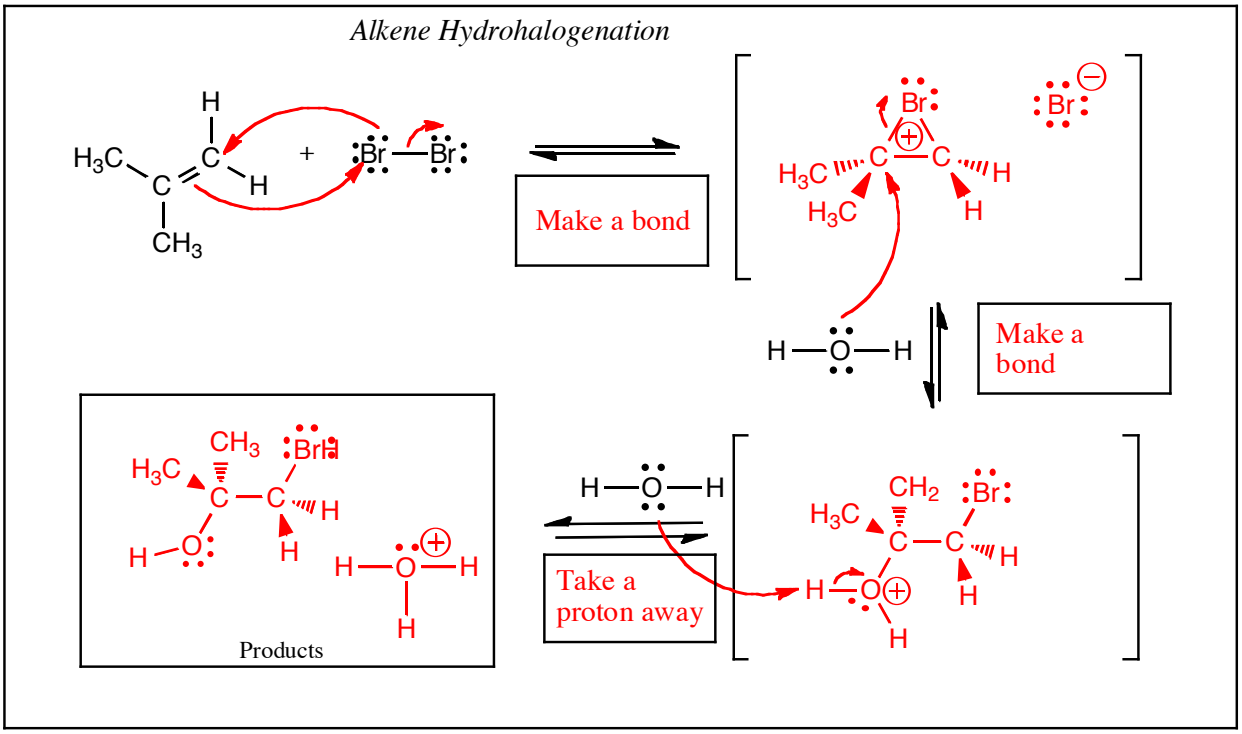
Diastereomers

(8 pts) In the two spaces below, draw the two equilibrating chair structures for the following cyclohexane derivative. Circle the one that predominates at equilibrium.

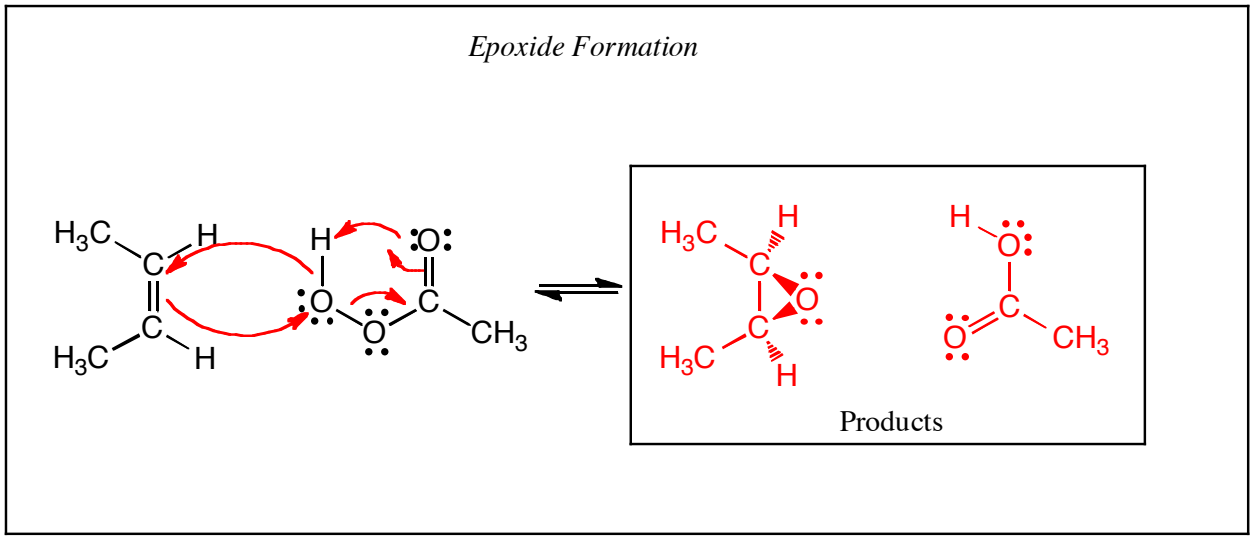




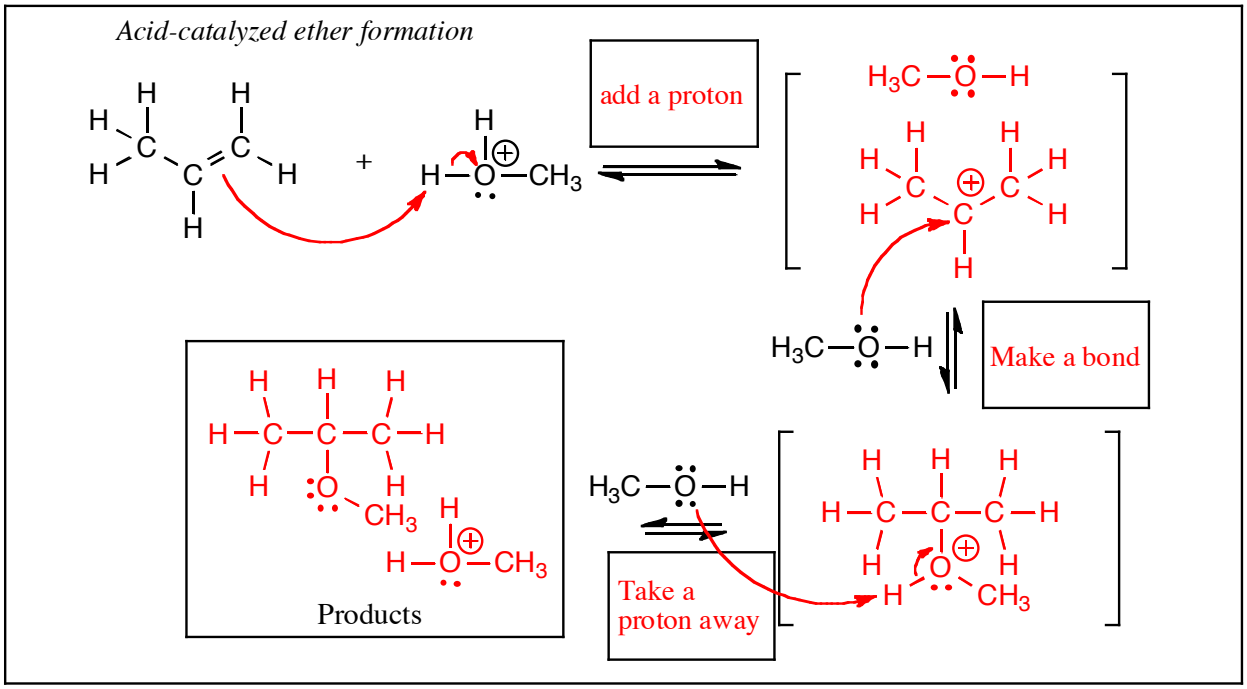
15. (26 pts.) Read these directions carefully. Read these directions carefully. (It was worth repeating) **For the following reactions, fill in the details of the mechanism. Draw the appropriate chemical structures and use an arrow to show how pairs of electrons are moved to** make and break bonds during the reaction. **For this question, you must draw all molecules produced in each step (yes, these equations need to be balanced!). Finally, fill in the 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, BUT if an intermediate or product is really a racemic mixture, you only need to draw one enantiomer and write racemic for this problem (we are making this easier for you).**

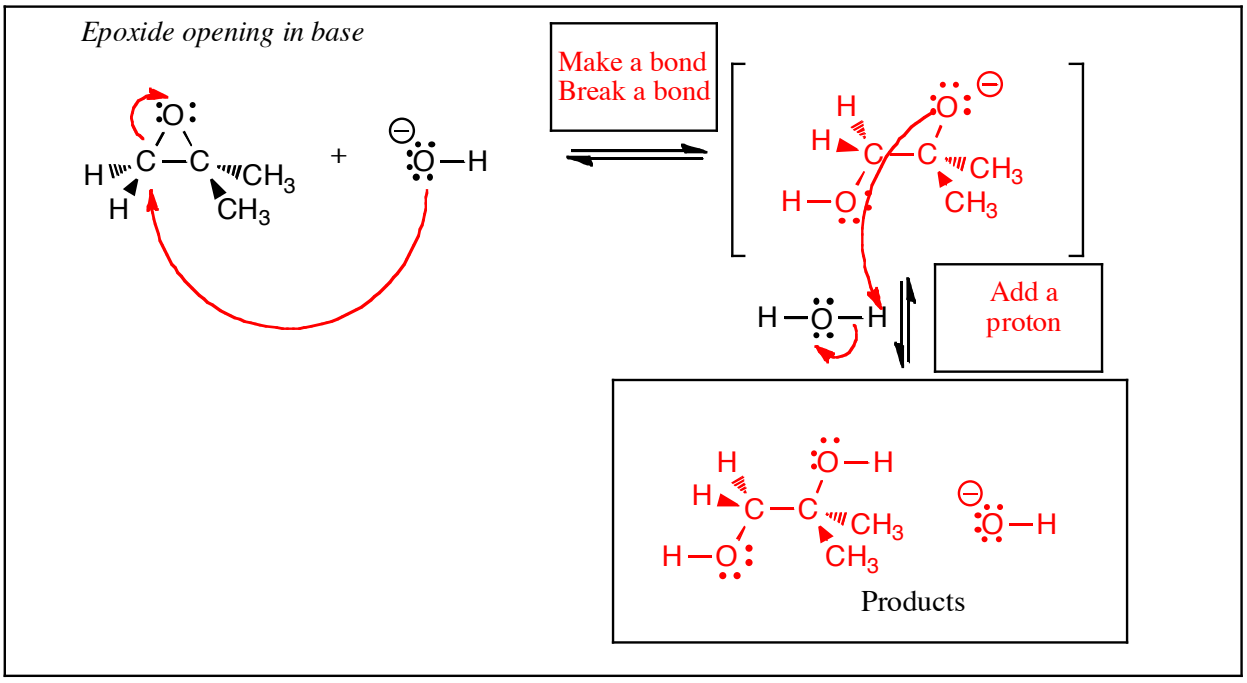


For this next one you do not need to describe the reaction using one of the four fundamental mechanistic steps ("Make a bond", etc.)

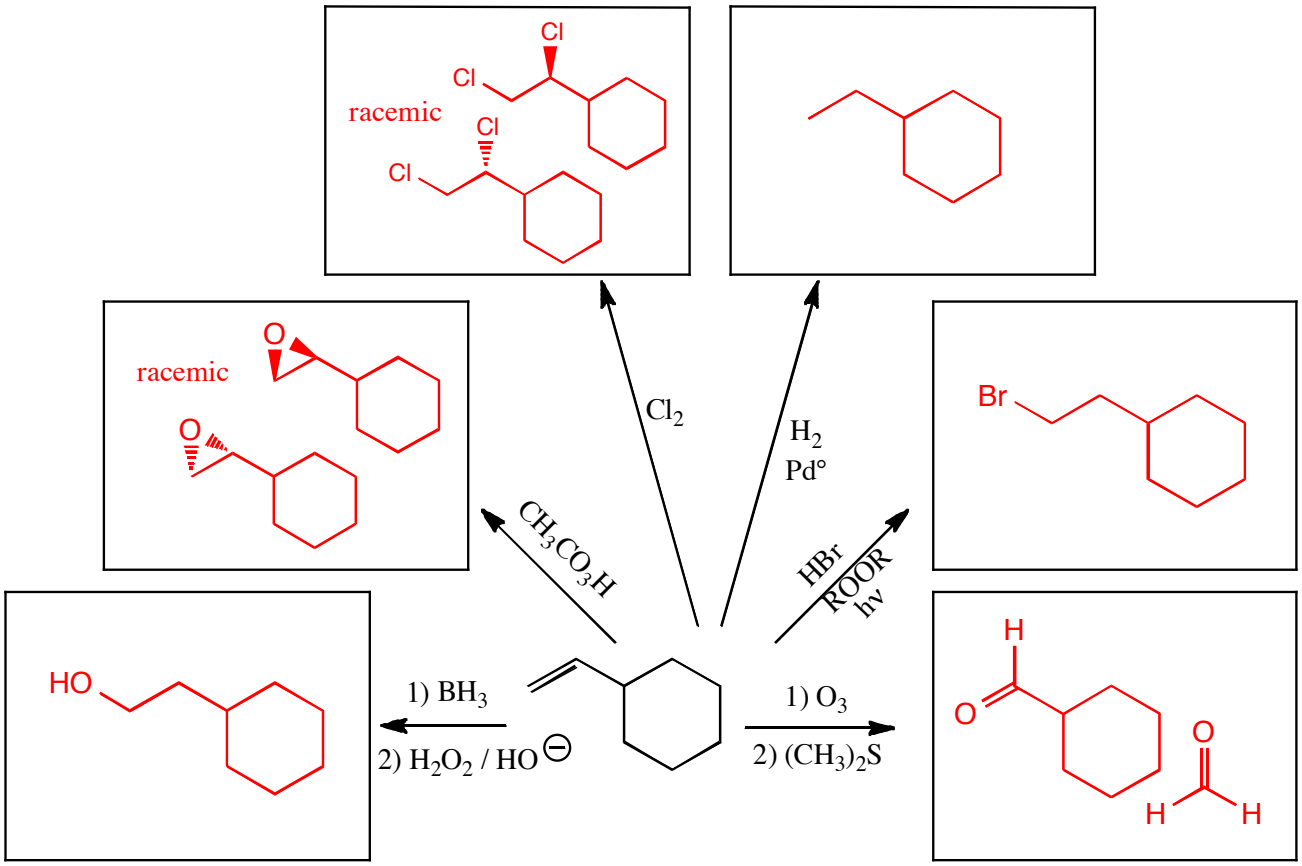


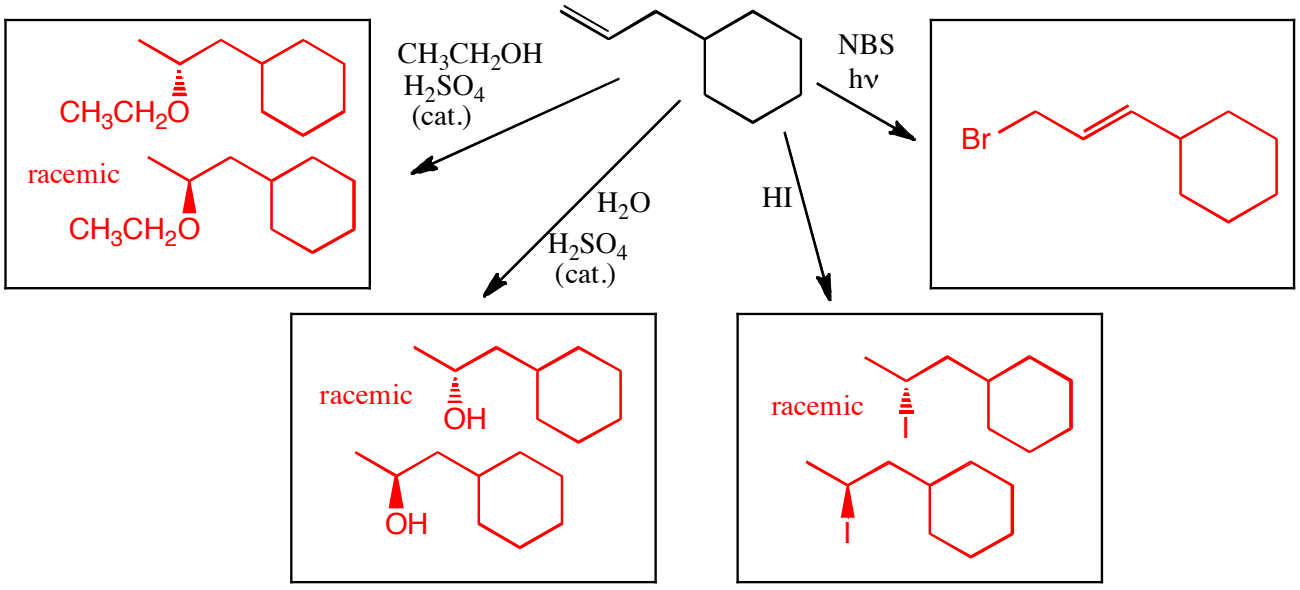
15. (22 pts.) Read these directions carefully. Read these directions carefully. (It was worth repeating) **For the following reactions, fill in the details of the mechanism. Draw the appropriate chemical structures and use an arrow to show how pairs of electrons are moved to** make and break bonds during the reaction. **For this question, you must draw all molecules produced in each step (yes, these equations need to be balanced!). Finally, fill in the 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, BUT if an intermediate or product is really a racemic mixture, you only need to draw one enantiomer then label it racemic for this problem (we are making this easier for you).**



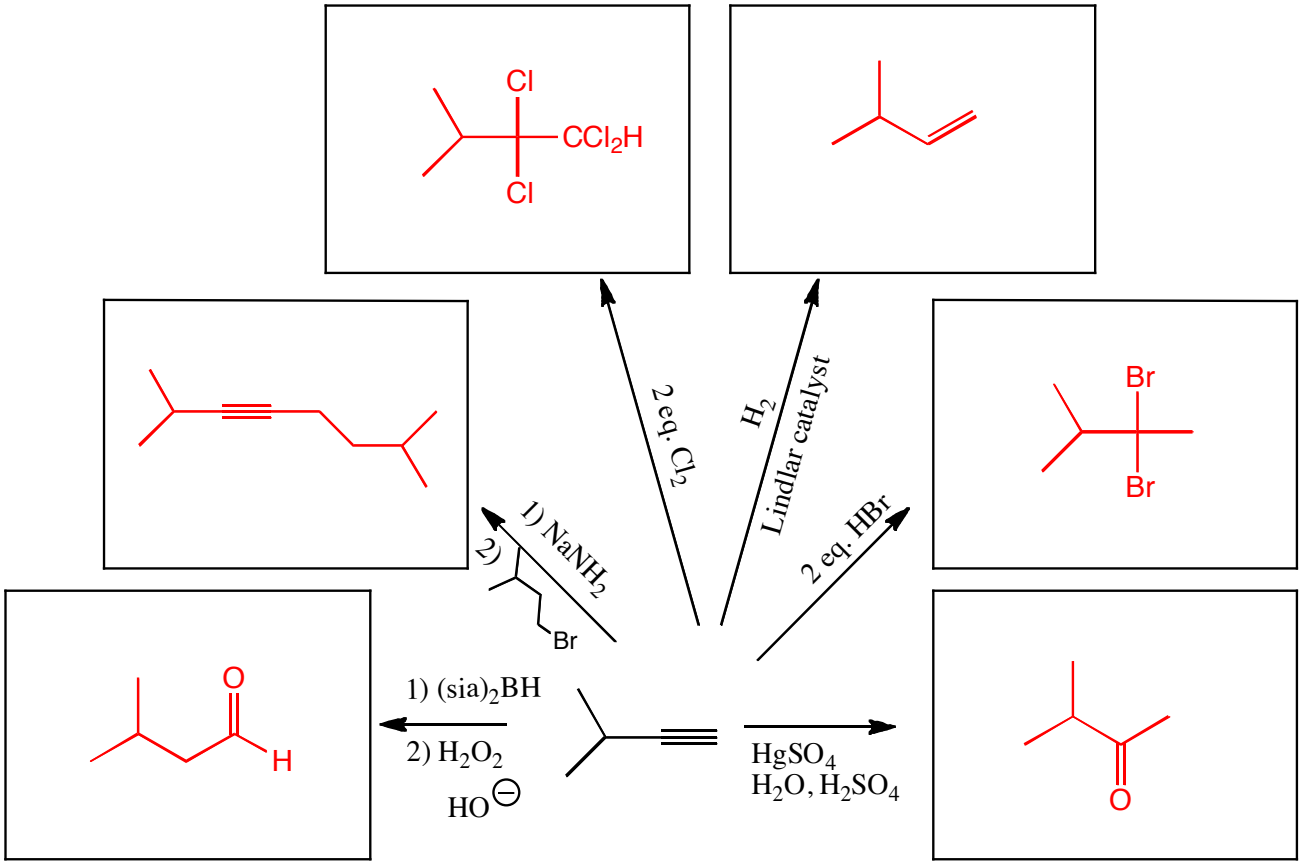


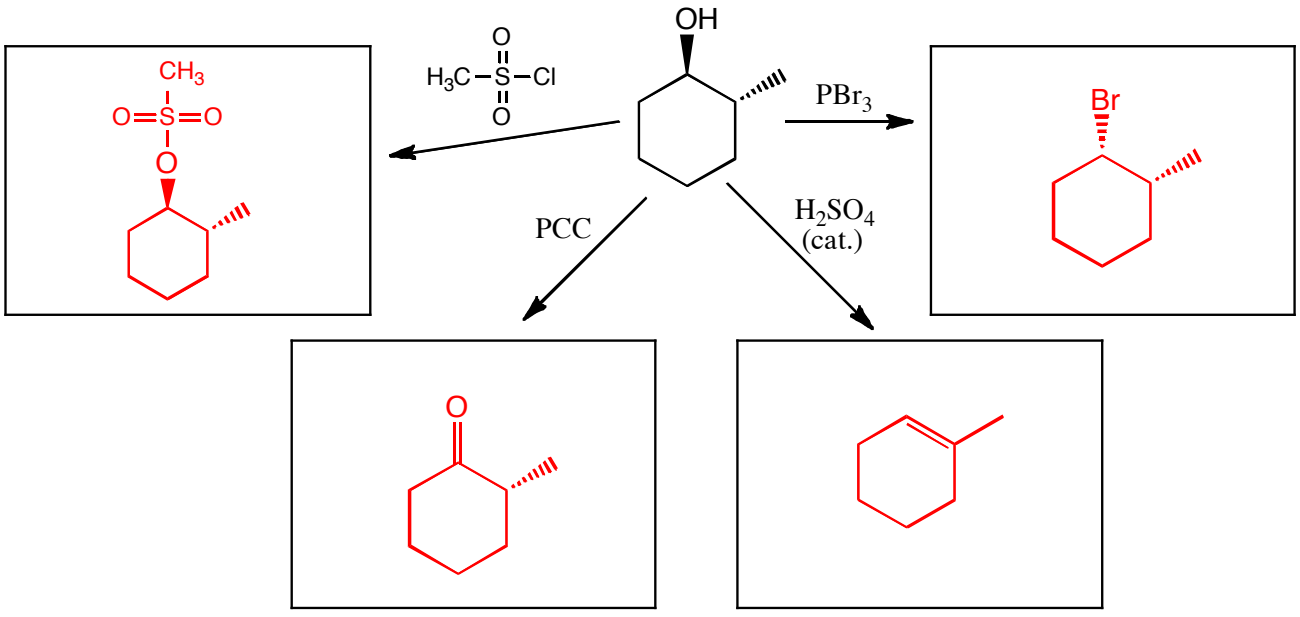
16. (3, 4 or 5 pts each) For the following, complete the reactions with the predominant product or products. You must indicate stereochemistry with wedges and dashes. You must draw all stereoisomers produced as predominant products and write "racemic" under the structures when appropriate. Assume no rearrangments take place.



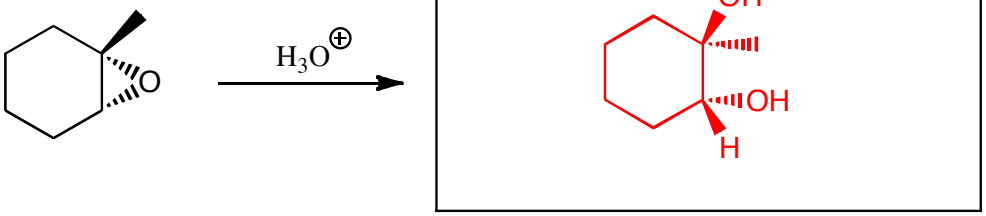


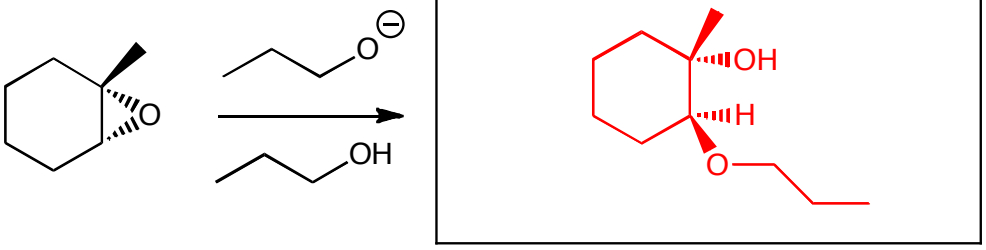
17. (3 or 5 pts each) For the following, complete the reactions with the predominant product or products. You must indicate stereochemistry with wedges and dashes. You must draw all stereoisomers produced as predominant products and write "racemic" under the structures when appropriate. Assume no rearrangments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

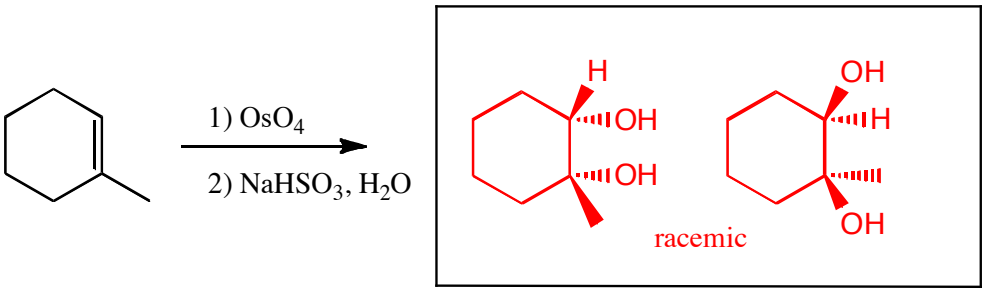


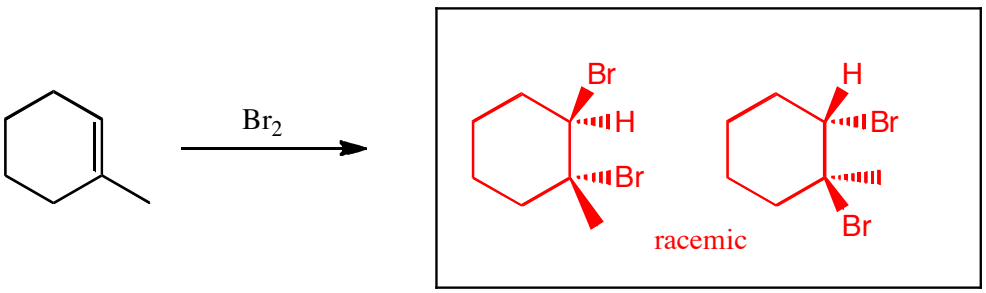


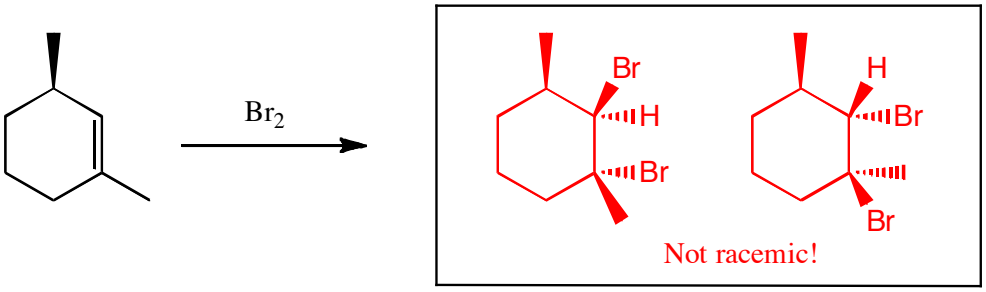
18. (3, 4 or 5 pts each) For the following, complete the reactions with the predominant product or products. You must indicate stereochemistry with wedges and dashes. You must draw all stereoisomers produced as predominant products and write "racemic" under the structures when appropriate. Assume no rearrangments take place.







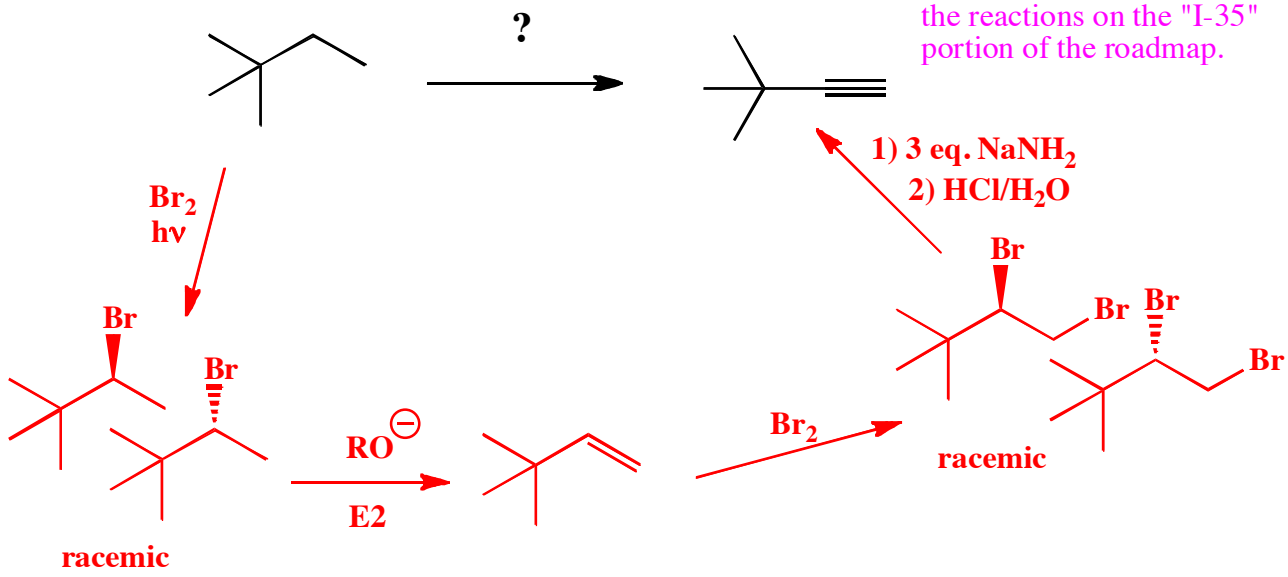




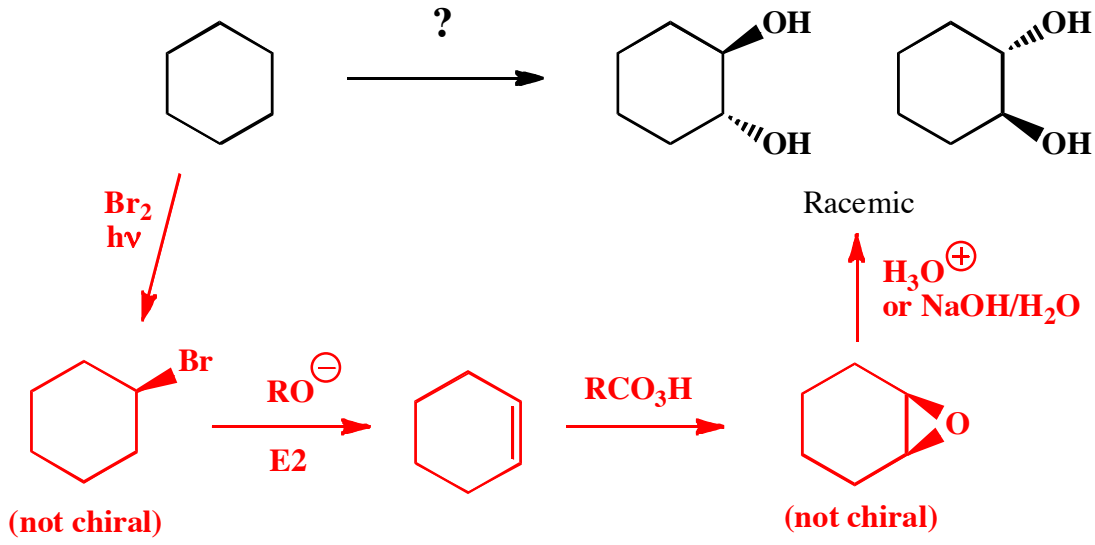
19. These are synthesis questions. You need to show how the starting material can be converted into the product(s) shown. You may use any reactions we have learned provided that the product(s) you draw for each step is/are the predominant one(s). Show all the reagents you need. Show each molecule synthesized 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.

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.



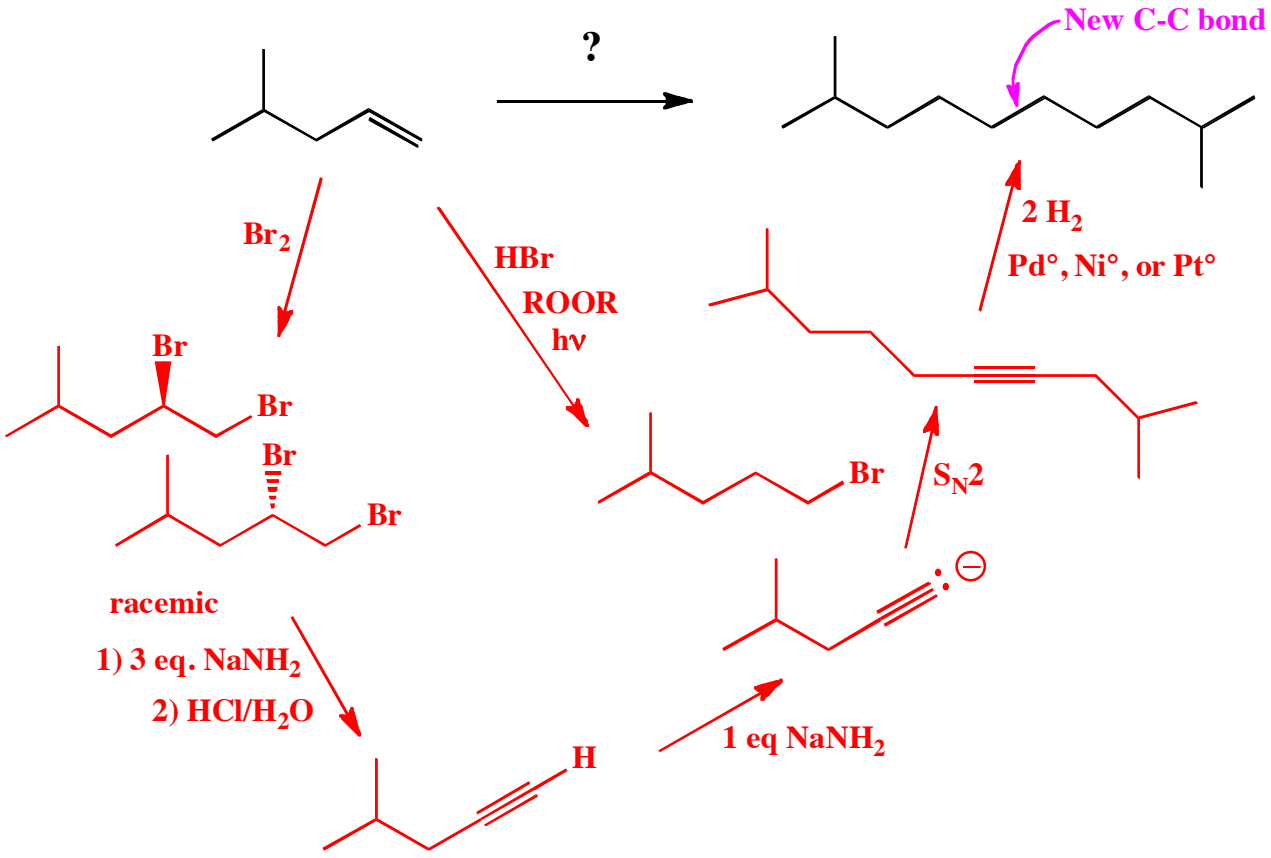
B) (10 pts)



Recognize the product as a trans vicinal diol, that can be made by reacting an epoxide in either acid or base. The epoxide can be made from cyclohexene by reaction with a peracid. The cyclohexene can be derived from the standard halogenation/E2 sequence of the "I-35" portion of the roadmap.

19. (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.**

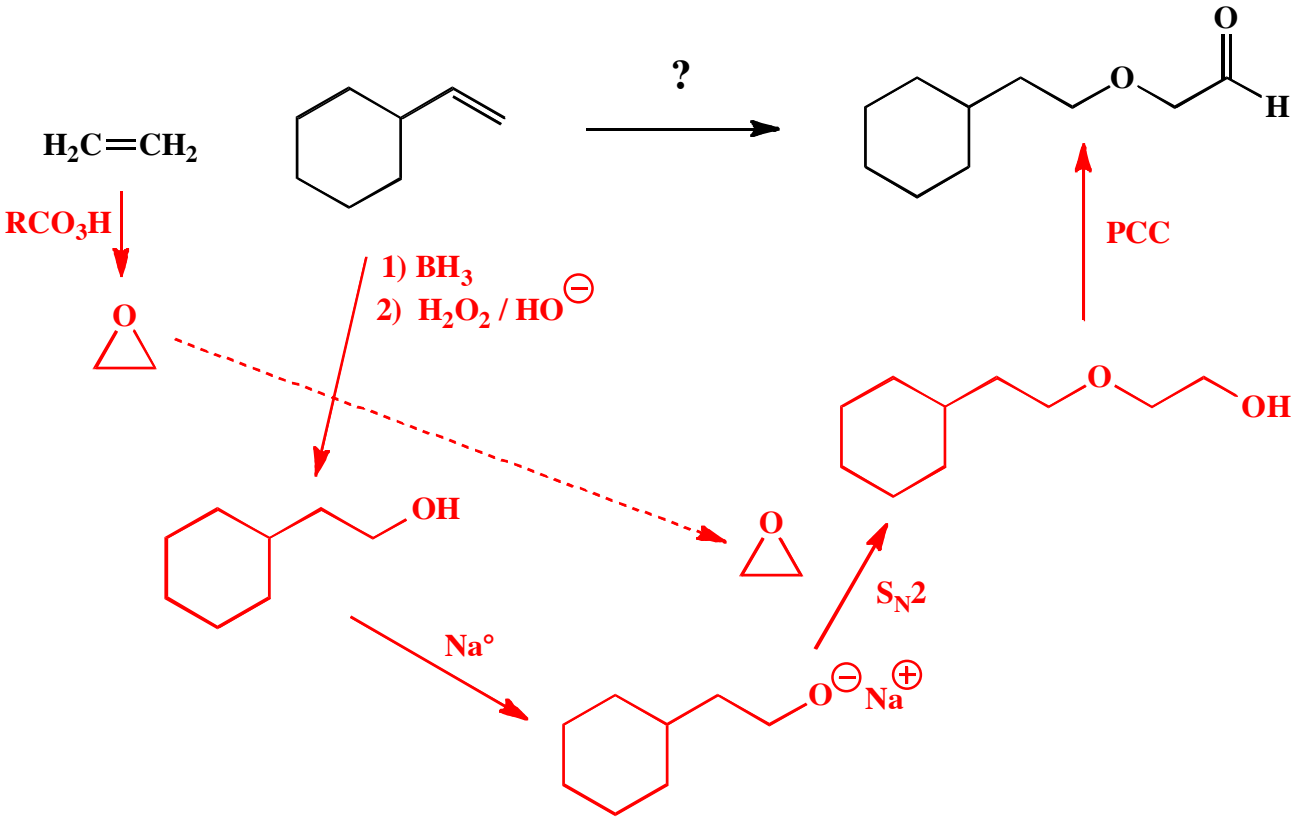
C) (15 pts)



Recognize that there are 12 carbons in the product and 6 in the starting material. Assume you need to put two starting material molecules together at the central bond as shown. The only way this can be done using the reactions you know is to react the anion of a terminal alkyne with a primary haloalkane. Therefore, assume there was once an alkyne in the molecule so predict that the last step is the hydrogenation of the alkyne to give the alkane. Continuing to work backwards, the required 12 carbon alkyne can be derived from the reaction of the 6 carbon primary haloalkane shown and the corresponding 6 carbon terminal alkyne. The primary haloalkane can be made in a single step from the starting alkene by using HBr in the presence peroxide and light. The terminal alkyne can be made using the familiar "I-35" sequence of steps involving reaction with Br_2 followed by reaction with the strong base $NaNH_2$.

19. (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.**

D) (12 pts)

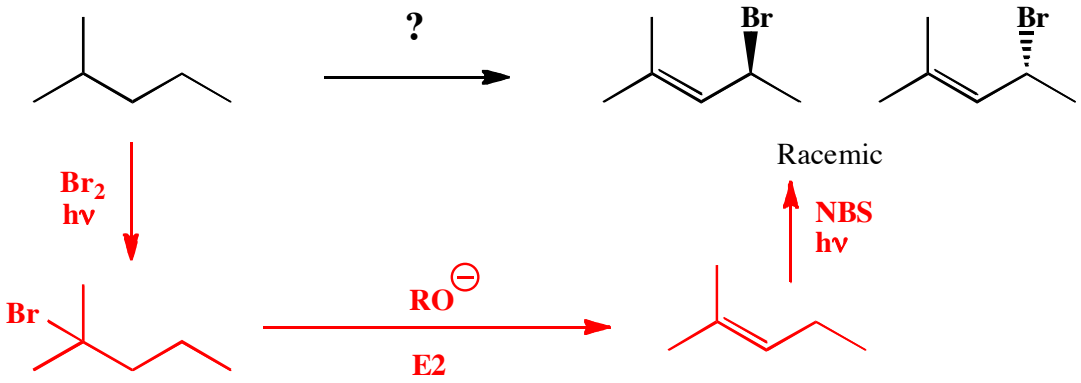


Recognize that the product has 10 carbons, and the starting materials have 8 and 2 carbons, respectively. Therefore assume the starting marterials are combined at the ether oxygen functional group. **Recognize** further that the product is an aldehyde. The only way to make an aldehyde that does not break a C-C bond is using PCC. Therefore predict that reaction with PCC is the last step and draw the corresponding ether-alcohol. **Recognize** that the ether-alcohol has the same pattern as the product of an alcohol reacting with an epoxide, an alcohol function two carbons from an ether. Predict the ether-alcohol is made from the reaction of the primary alcohol shown with ethylene oxide, the two-carbon epoxide. I illustrated this in base by making the alkoxide. You could also carry out the reaction in catalytic acid and save a step. The required alcohol comes from the non-Markovnikov hydroboration of the starting alkene, and ethylene oxide can be made from the starting material ethylene through reaction with a peracid.

Alternative you could have also made the ether-alcohol by reacting the primary alcohol or alkoxide with 1,2-dibromoethane (Williamson ether synthesis) followed by conversion of the primary Br to an OH group by reaction with NaOH or H_2O. The 1,2-dibromoethane can be made by reation of the starting ethylene with Br_2.

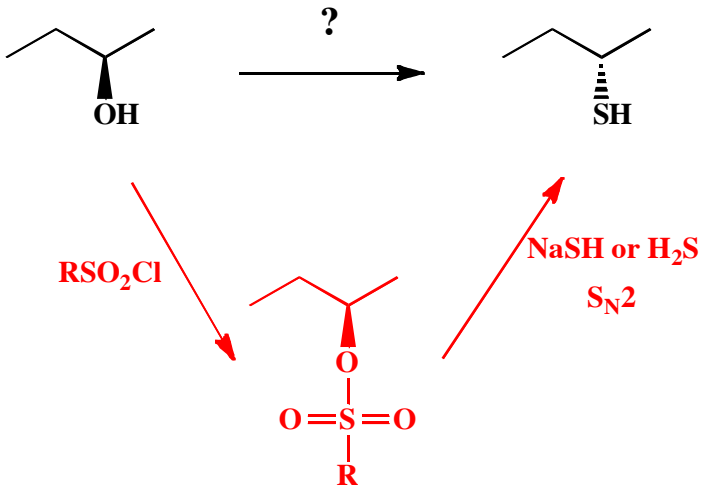
19. (cont.) These are synthesis questions. You need to show how the starting material can be converted into the product(s) shown. You may use any reactions we have learned provided that the product(s) you draw for each step is/are the predominant one(s). Show all the reagents you need. Show each molecule 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.**

E) (7 pts)



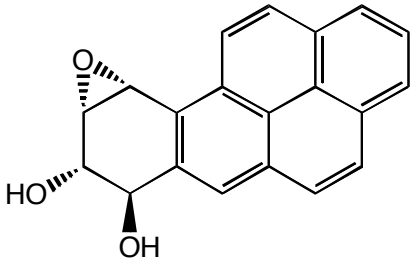
Recognize that the product is the result of the allylic halogenation of an alkene, predict therefore that the last reaction uses NBS. **Recognize** further that the required alkene for the last step is the Zaitsev product after an E2 reaction of the bromoalkane, that itself is the predominant product of free radical halogenation of the starting alkane.

F) (4 pts)



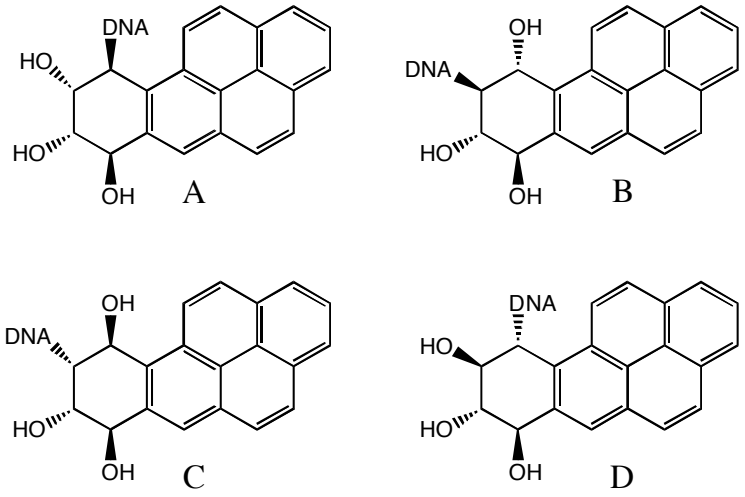
Recognize that the stereochemistry of the product is the result of a single **InVERSiON** of the starting alcohol chiral center. Therefore, use the sequence of reaction with a sulfonyl chloride followed by an S_N2 reaction with either NaSH or H_2S.

20. A number of molecules are dangerous because they make a covalent bond to DNA, causing a mutation when the cell with the modified DNA divides. A characteristic of these molecules is that they are electrophiles. Often, they interact strongly with the DNA before the covalent bond forms. This so-called preassociation greatly speeds up the reaction and helps target the DNA. A potent carcinogen is the benzopyrene diol epoxide. It is a metabolized byproduct of benzopyrene, a compound found in barbecued meats cooked over an open hot flame.



Benzopyrene diol epoxide

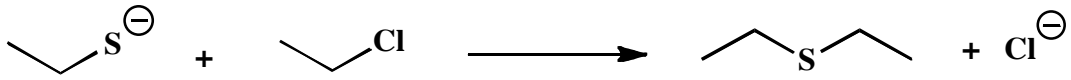
The large flat overall structure of the molecule helps it slip between the stacked base pairs of the DNA double helix, then the DNA reacts as a nucleophile with the benzopyrene diol epoxide.



Which of these products could be produced when the benzopyrene diol epoxide stereoisomer shown above reacts with DNA?

A) Only product C could be produced
B) Only A and B could be produced
C) Only C and D could be produced
D) All four are produced.

It turns out that many other electrophiles are dangerous as well. The nerve gas Sarin as well as the chemical warfare agent mustard gas are both electrophiles. In each case, these electrophiles react with important molecules in our bodies. The new covalent bonds that form inactivate the important molecules, explaining why Sarin and mustard gas are so deadly. For protection, our bodies have catalysts called glutathione S-transferases that react with electrophiles and prevent their doing damage. It is critical that you can quickly identify nucleophiles and electrophiles in reactions. Find the answer that best describes the following reaction:



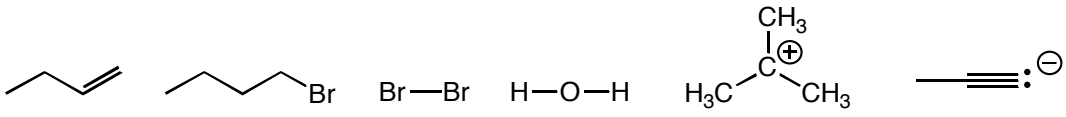
A) In this reaction, the negatively charged S atom is the nucleophile and so is the chloroalkane
B) In this reaction, the negatively charged S atom is the nucleophile, and the chloroalkane is the electrophile
C) In this reaction, the negatively charged S atom is the electrophile, and the chloroalkane is the nucleophile
D) In this reaction, the negatively charged S atom is the electrophile and so is the chloroalkane

It is essential that you learn to recognize nucleophiles and electrophiles. Below are two potential nucleophiles:

A B

A) The structure labeled A is a better nucleophile compared to B.
B) The structure labeled B is a better nucleophile compared to A.
C) The structure labeled A and the structure labeled B are equally strong nucleophiles.
D) Neither structure is a nucleophile.

Consider the following series of molecules we have seen this semester:



A B C D E F

A) Structures C,D,and E are electrophiles, while structures A, B and F are nucleophiles.
B) Structures A,B, C and E are electrophiles, while structures D and F are nucleophiles.
C) Structures B, C and E are electrophiles, while structures A, D and F are nucleophiles
D) Structures B, and E are electrophiles, while structures A, C, D and F are nucleophiles