NAME (Print): _____

SIGNATURE: _____

Chemistry 320M/328M
Dr. Brent Iverson
2nd Midterm
October 26, 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		(23)
2		(30)
3		(28)
4		(18)
5		(12)
6		(24)
7		(22)
8		(30)
9		(-)
10		(21)
11		(21)
12		(15)
13		(16)
14		(13)
Total		(273)

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)

PERIODIC TABLE OF THE ELEMENTS

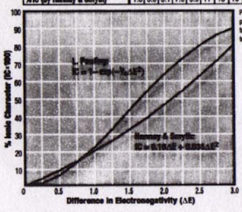
▼ Elementary Subatomic Particles

	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)	5.4857990(13) x 10^{-7}	1.0072764(10) x 10^{-3}	1.0086649(14) x 10^{-3}	0	≈ 0
Particle-electron mass ratio	1	1836.152701(37)	1838.683662(40)	0	≈ 0
Particle-proton mass ratio	5.4461703(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)	−1.7588196(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)	2.4263105B(22) x 10^{-12}	1.321410D2(12) x 10^{-15}	1.319591I0(12) x 10^{-15}	–	–
Magnetic moment (J/T); μ	928.47701(31) x 10^{-26}	1.410607I(47) x 10^{-26}	0.96623707(40) x 10^{-26}	0	0
In Bohr magnetons; μ/μ_B	1.0011596521I(10)	1.521032202(15) x 10^{-3}	1.0417363(25) x 10^{-3}	0	0
In nuclear magnetons; μ/μ_N	1838.282000(37)	2.792847386(63)	1.9130427(5/45)	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 ($\mu$) 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 = 5.0507699(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)	1.6	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

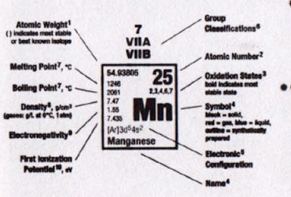


Percent ionic character describes the nature of a bond. Bonds possessing 50% or greater ionic character are commonly termed ionic; bonds with less than 50% ionic character are termed covalent. Pauling's equation was modified by Hanney & Smyth in order to achieve better agreement between experimental 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	2 IIA	3 IIIA IIIB	4 IVA IVB	5 VA VB	6 VIA VIB	7 VIIA VIIB	8 VIIIA VIII	9 VIIIA VIII	10 VIIIA VIII	11 IB IB	12 IIB IIB	13 IIIB IIIA	14 IVB IVA	15 VB VA	16 VIB VIA	17 VIIB VIIA	18 VIII 0
1.00794 −259.34 −252.87 0.0899 2.20 13.598 1s¹	1 **H** Hydrogen																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 **C** Carbon	14.00674 −210.00 −195.79 1.25046 3.04 14.534 [He]2s²2p³	7 **N** Nitrogen	15.9994 −218.79 −182.95 1.429 3.44 13.618 [He]2s²2p⁴	8 **O** Oxygen	18.9984032 −219.62 −188.12 1.69 3.98 17.422 [He]2s²2p⁵	9 **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 **Al** Aluminum	28.0855 1414 3265 2.33 1.90 8.151 [Ne]3s²3p²	14 **Si** Silicon	30.973762 44.15 277 1.82 2.19 10.486 [Ne]3s²3p³	15 **P** Phosphorus	32.066 115.21 444.60 2.07 2.58 10.360 [Ne]3s²3p⁴	16 **S** Sulfur	35.4527 −101.5 −34.04 3.214 3.16 12.967 [Ne]3s²3p⁵	17 **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 **Ca** Calcium	44.955910 1541 2830 2.989 1.36 6.54 [Ar]3d¹4s²	21 **Sc** Scandium	47.88 1668 3287 4.5 1.54 6.82 [Ar]3d²4s²	22 **Ti** Titanium	50.9415 1910 3407 5.96 1.63 6.74 [Ar]3d³4s²	23 **V** Vanadium	51.9961 1907 2671 7.20 1.66 6.766 [Ar]3d⁵4s¹	24 **Cr** Chromium	54.93805 1246 2061 7.47 1.55 7.435 [Ar]3d⁵4s²	25 **Mn** Manganese	55.847 1538 2861 7.86 1.83 7.870 [Ar]3d⁶4s²	26 **Fe** Iron	58.93320 1495 2927 8.92 1.88 7.86 [Ar]3d⁷4s²	27 **Co** Cobalt	58.6934 1455 2913 8.90 1.91 7.635 [Ar]3d⁸4s²	28 **Ni** Nickel	63.546 1084.62 2562 8.94 1.90 7.726 [Ar]3d¹⁰4s¹	29 **Cu** Copper	65.39 419.53 907 7.14 (20°C) 1.65 9.394 [Ar]3d¹⁰4s²	30 **Zn** Zinc	69.723 29.76 2204 5.904 1.81 5.999 [Ar]3d¹⁰4s²4p¹	31 **Ga** Gallium	72.61 936.25 2833 5.35 2.01 7.899 [Ar]3d¹⁰4s²4p²	32 **Ge** Germanium	74.92159 817* 614* 5.727 (25°C) 2.05 9.81 [Ar]3d¹⁰4s²4p³	33 **As** Arsenic	78.96 221 685 4.81 2.55 9.752 [Ar]3d¹⁰4s²4p⁴	34 **Se** Selenium	79.904 −7.2 58.8 3.119 2.96 11.814 [Ar]3d¹⁰4s²4p⁵	35 **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 5.866 [Kr]5s²	38 **Sr** Strontium	88.90585 1526 3336 4.469 1.22 6.38 [Kr]4d¹5s²	39 **Y** Yttrium	91.224 1855 4409 6.49 1.33 6.84 [Kr]4d²5s²	40 **Zr** Zirconium	92.90638 2477 4744 8.57 1.6 6.9 [Kr]4d⁴5s¹	41 **Nb** Niobium	95.94 2623 4639 10.2 2.16 7.099 [Kr]4d⁵5s¹	42 **Mo** Molybdenum	(97.9072) 2157 4265 11.5 1.9 7.28 [Kr]4d⁵5s²	43 **Tc** Technetium	101.07 2334 4150 12.3 2.2 7.37 [Kr]4d⁷5s¹	44 **Ru** Ruthenium	102.90550 1964 3695 12.4 2.28 7.46 [Kr]4d⁸5s¹	45 **Rh** Rhodium	106.42 1554.9 2963 12.02 2.20 8.34 [Kr]4d¹⁰	46 **Pd** Palladium	107.8682 961.78 2162 10.5 1.93 7.576 [Kr]4d¹⁰5s¹	47 **Ag** Silver	112.411 321.07 767 8.642 1.69 8.993 [Kr]4d¹⁰5s²	48 **Cd** Cadmium	114.818 156.60 2024 7.30 1.78 5.786 [Kr]4d¹⁰5s²5p¹	49 **In** Indium	118.710 231.93 2833 7.28 1.96 7.344 [Kr]4d¹⁰5s²5p²	50 **Sn** Tin	121.757 630.63 1587 6.684 (25°C) 2.05 8.641 [Kr]4d¹⁰5s²5p³	51 **Sb** Antimony	127.60 449.51 988 6.25 2.1 9.009 [Kr]4d¹⁰5s²5p⁴	52 **Te** Tellurium	126.90447 113.7 184.4 4.93 2.66 10.451 [Kr]4d¹⁰5s²5p⁵	53 **I** Iodine	131.29 −111.75 −108.04 5.89 – 12.130 [Kr]4d¹⁰5s²5p⁶	54 **Xe** Xenon
(223.0197) 27 677 – 0.7 – [Rn]7s¹	87 **Fr** Francium	(226.0254) 700 <1140 0.8 0.9 5.279 [Rn]7s²	88 **Ra** Radium	(227.0278) 1051 3198 10.07 1.1 6.9 [Rn]6d¹7s²	89 ** **Ac** Actinium	(261.11) – – – – – [Rn]5f¹⁴6d²7s²	104 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	(268) – – – – – [Rn]5f¹⁴6d⁷7s²	109 Une Unnilennium	(272) – – – – – [Rn]5f¹⁴6d⁸7s²	110 Uun Ununnium								

●	●●
140.115 799 3424 6.770 1.12 5.466 [Xe]4f¹5d¹6s²	58 **Ce** Cerium
232.0381 1750 4788 11.72 1.3 6.06 [Rn]6d²7s²	90 **Th** Thorium
140.90765 931 3510 6.773 1.13 5.422 [Xe]4f³6s²	59 **Pr** Praseodymium
231.03588 1572 – 15.37 1.5 5.89 [Rn]5f²6d¹7s²	91 **Pa** Protactinium
144.24 1016 3056 7.00 1.14 5.489 [Xe]4f⁴6s²	60 **Nd** Neodymium
238.0289 1135 4131 19.05 α,β 1.38 6.05 [Rn]5f³6d¹7s²	92 **U** Uranium
(144.9127) 1042 3000 7.264 1.13 5.554 [Xe]4f⁵6s²	61 **Pm** Promethium
(237.0482) 644 3228 19.816 1.28 5.8 [Rn]5f⁴6d¹7s²	93 **Np** Neptunium
150.36 1072 1700 7.536 1.17 5.631 [Xe]4f⁶6s²	62 **Sm** Samarium
(244.0642) 640 3228 19.816 1.28 5.8 [Rn]5f⁶7s²	94 **Pu** Plutonium
151.965 822 1596 5.244 1.2 5.666 [Xe]4f⁷6s²	63 **Eu** Europium
(243.0614) 1176 2607 13.67 1.3 5.993 [Rn]5f⁷7s²	95 **Am** Americium
157.25 1314 3264 7.901 1.20 6.141 [Xe]4f⁷5d¹6s²	64 **Gd** Gadolinium
(247.0703) 1345 – 13.51 1.3 6.02 [Rn]5f⁷6d¹7s²	96 **Cm** Curium
158.92534 1359 3221 8.230 1.2 5.842 [Xe]4f⁹6s²	65 **Tb** Terbium
(247.0703) 1050 – 14.78 1.3 6.23 [Rn]5f⁹7s²	97 **Bk** Berkelium
162.50 1411 2561 8.551 1.22 5.927 [Xe]4f¹⁰6s²	66 **Dy** Dysprosium
(251.0796) 900 – 15.1 1.3 6.30 [Rn]5f¹⁰7s²	98 **Cf** Californium
164.93032 1472 2694 8.795 1.24 6.018 [Xe]4f¹¹6s²	67 **Ho** Holmium
(252.083) 800 – – 1.3 6.42 [Rn]5f¹¹7s²	99 **Es** Einsteinium
167.26 1529 2862 9.066 1.24 6.101 [Xe]4f¹²6s²	68 **Er** Erbium
(257.0951) 1527 – – 1.3 6.50 [Rn]5f¹²7s²	100 **Fm** Fermium
168.93421 1545 1946 9.321 1.25 6.18436 [Xe]4f¹³6s²	69 **Tm** Thulium
(258.10) 827 – – 1.3 6.58 [Rn]5f¹³7s²	101 **Md** Mendelevium
173.04 824 1194 6.966 1.1 6.25394 [Xe]4f¹⁴6s²	70 **Yb** Ytterbium
(259.1009) 827 – – 1.3 6.65 [Rn]5f¹⁴7s²	102 **No** Nobelium
174.967 1663 3393 9.84 1.27 6.42549 [Xe]4f¹⁴5d¹6s²	71 **Lu** Lutetium
(262.11) 1627 – – – – [Rn]5f¹⁴6d¹7s²	103 **Lr** Lawrencium

*Indicates approximate values and/or inconsistent literature data.



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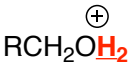
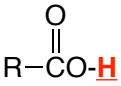
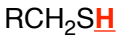
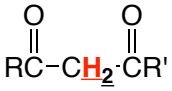
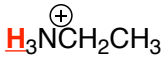
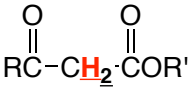
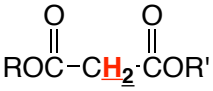
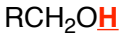
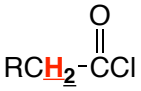
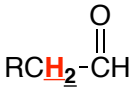
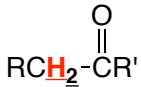
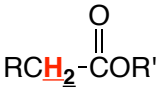
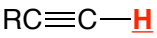
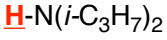
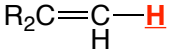
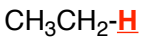
PAPERTECH

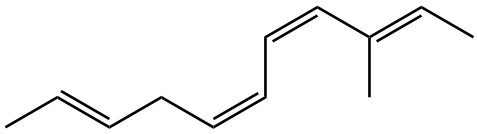
The data for this reference guide were obtained from the latest scientific and government sources (IUPAC, CODATA, National Bureau of Standards, etc.). Estimated values and/or inconsistent data are marked with an asterisk (*).
1. Ratio of the average mass per atom of the element to 1/12 of the mass of an atom of ^{12}C. 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 older group classifications systems still in use today rely on an A/B sorting scheme to categorize periodic properties. Because of the potential for confusion between these two systems (i.e., IIIA in one scheme is equal to IIIB 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; TP = 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).

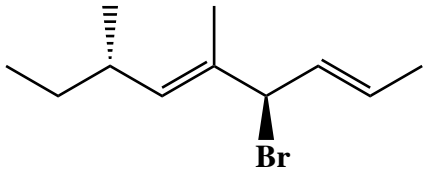
Compound		pK_a
Hydrochloric acid		-7
Protonated alcohol		-2
Hydronium ion		-1.7
Carboxylic acids		3-5
Thiols		8-9
Ammonium ion		9.2
β-Dicarbonyls		10
Primary ammonium		10.5
β-Ketoesters		11
β-Diesters		13
Water		15.7
Alcohols		15-19
Acid chlorides		16
Aldehydes		18-20
Ketones		18-20
Esters		23-25
Terminal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

Signature_____ Pg 1 _____(23)

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

2. (12 pts) Write an acceptable IUPAC name for the following two molecules. Where appropriate, use E and Z or R and S.

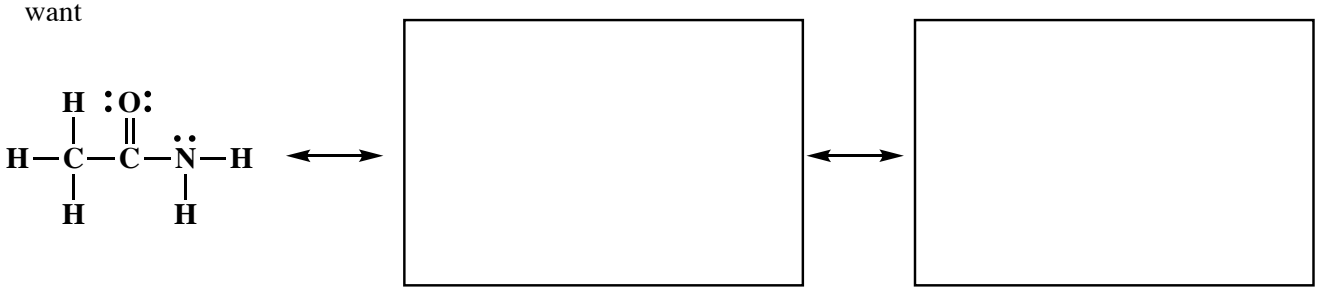




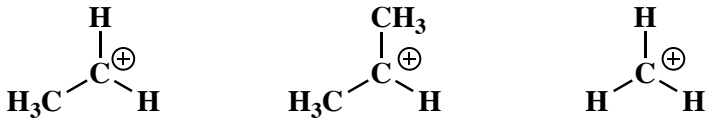
3. (6 pts) Draw the structure that corresponds to the following name:

(2*E*,4*Z*)-3,5-dimethyl-2,4-heptadiene

4. (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



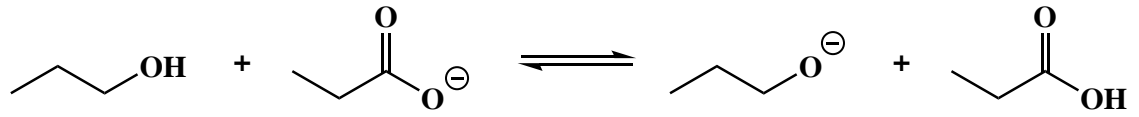
5. (2 pts each) Consider the three structures below, then fill in each space with the letter, word or number that best completes each of the following sentences.

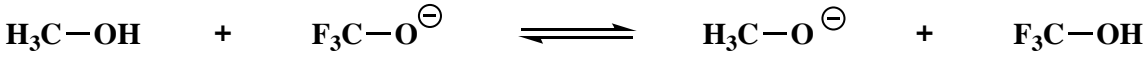


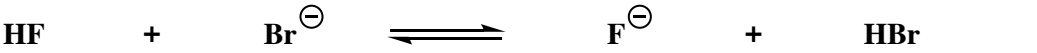
A **B** **C**

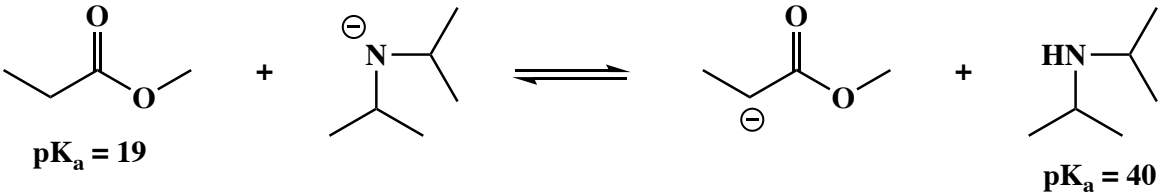
The letter that corresponds to the most stable of the three carbocations shown above is _____ . The most stable carbocation is the one that is _____ (lowest or highest) in energy. The hybridizaton state of the positively-charged carbon atom in the most stable carbocation is _____ . For the most stable carbocation, there are _____ (a number) total C-H sigma bonds that overlap with the empty _____ orbital of the postitively-charged C atom, providing stabilization via an interaction called _____ . The most stable carbocation is stabilized by a second effect called the _____ effect. For this second interaction on the most stable carbocation, electron density is drawn to the positively-charged carbon atom from _____ (a number) other carbon atom(s). This happens because of the fact that the positively-charged carbon atom is _____ (more or less) electronegative than a carbon atom with no full positive charge. The most stable carbocation above is referred to as a _____ (methyl, primary, secondary or tertiary) carbocation.

6. (10 pts) For each acid-base reaction, **circle the side of the equation that predominates at equilibrium.**



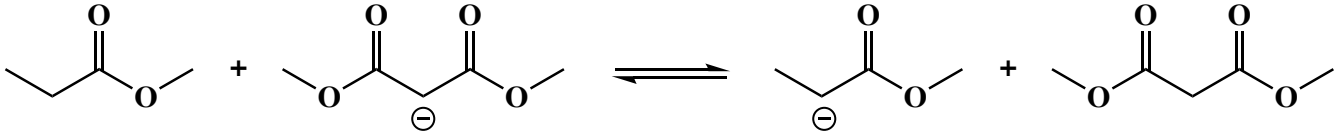






$pK_a = 19$ $pK_a = 40$

Think about this last one!



7. (2 or 4 pts each) For the following, **circle the capitalized word** that best completes the statement.

In general, it is best to think of alkenes as NUCLEOPHILES or ELECTROPHILES that react with NUCLEOPHILES or ELECTROPHILES such as Br_2.

In general, NUCLEOPHILES or ELECTROPHILES serve as electron sources and NUCLEOPHILES or ELECTROPHILES serve as electron sinks for the arrows used to indicate bond-making steps in reactions.

A pi bond or lone pair will serve as an ELECTRON SOURCE or ELECTRON SINK for an arrow that indicates the making of a new bond.

An atom that can accommodate a new bond can serve as an ELECTRON SOURCE or ELECTRON SINK for an arrow that indicates the making of a new bond.

A reaction that occurs slower generally has a LOWER or HIGHER activation energy.

A reaction that has a strong thermodynamic driving force (a strong motive) is FAVORABLE or UNFAVORABLE as written.

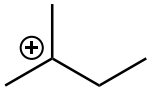
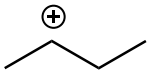
A reaction will have a strong motive (thermodynamic driving force) if the bonds made are STRONGER or WEAKER than the bonds that are broken.

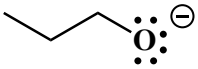
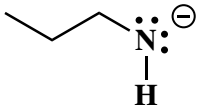
8. (2 pts each) Write the mechanistic element (of the four) that is appropriate when you see the following species in a mechanism:

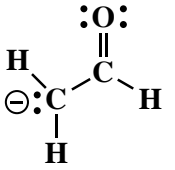
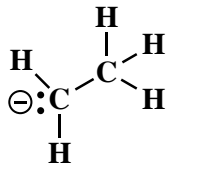
A nucleophile and an electrophile are present	_____
The carbon containing species is a weak base and there is a strong acid present	_____
The carbon containing species is a strong acid and a base is present	_____
The carbon containing species can fragment to make water and a tertiary carbocation	_____

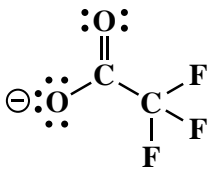
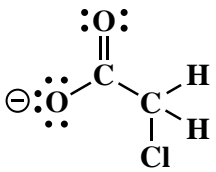
9. (2 pts each no partial credit) The following statements are true. Choose from among the following five possibilities and in the space provided, write the letter of the one *or more* phenomena that best explain the true statement.

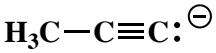
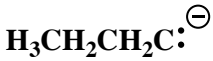
A. The inductive effect **B. Hyperconjugation** **C. Resonance delocalization of a charged species**
D. Greater s character of the orbital containing an electron pair on a negatively-charged atom **E. The negative charge is on a more electronegative element**

 **is lower in energy than**  **because of:** _____

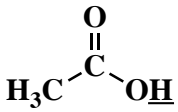
 **is lower in energy than**  **because of:** _____

 **is lower in energy than**  **because of:** _____

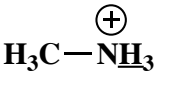
 **is lower in energy than**  **because of:** _____

 **is lower in energy than**  **because of:** _____

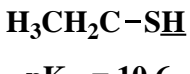
10. (12 pts) **Complete the following two structures by adding appropriate numbers of lone pair electrons, H atoms, and formal charges to the atoms in the boxes.** You must adjust your answers to indicate the predominant species at each indicated pH value. (You do not have to add anything such as H atoms to atoms not drawn in the boxes.) This problem is testing your understanding of the relationship of protonation state to pH to pKa values for certain functional groups we have discussed. **Next, in the space provided, write the overall charge on each structure at the indicated pH. For your reference, here are the relevant pK_a values:**



pK_a = 4.76

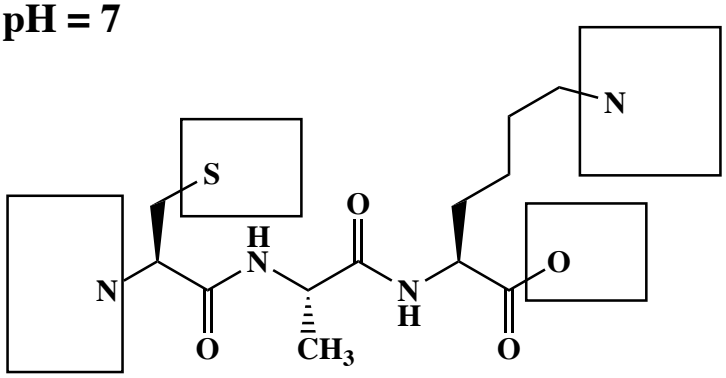


pK_a = 10.64



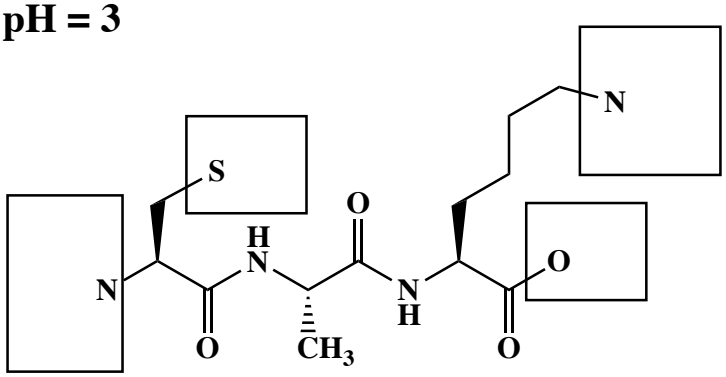
pK_a = 10.6

pH = 7



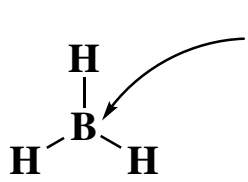
Total charge on molecule:_____

pH = 3



Total charge on molecule:_____

11. (2 pts each) **Complete** the following set of questions related to derivatives of boron.

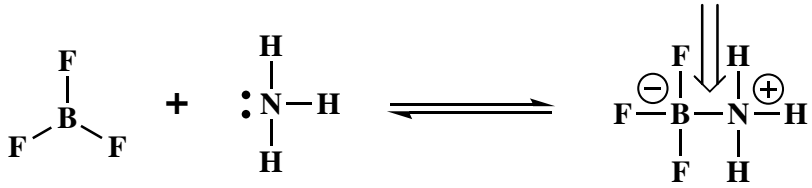


The BH_3 molecule has _____ valence electrons around the B atom.

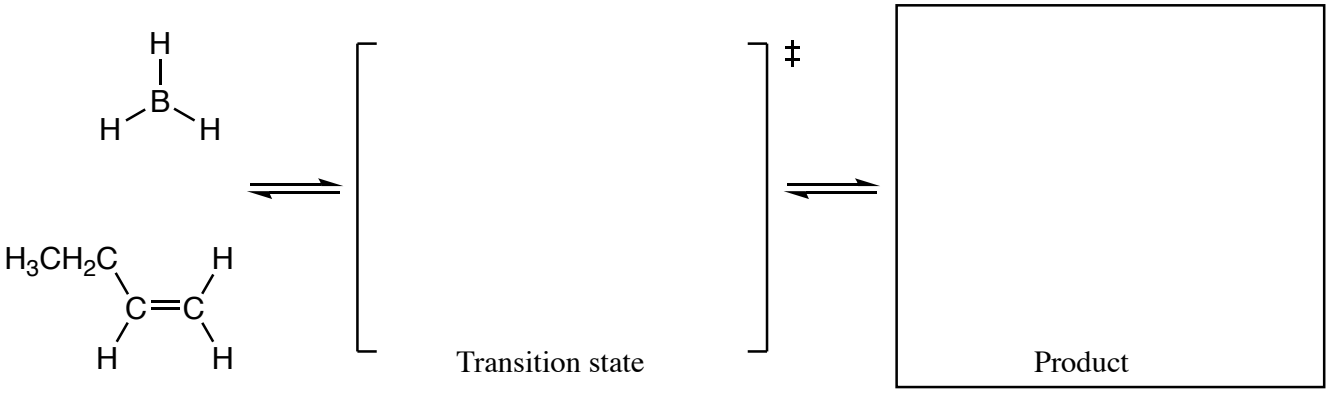
The BH_3 molecule is best considered a Lewis _____ .

In the BH_3 molecule, there is an empty _____ orbital on the B atom.

Related molecules such as BF_3 react with ammonia to create a special type of bond known as a _____ bond that is illustrated in the following equation and indicated by the arrow:



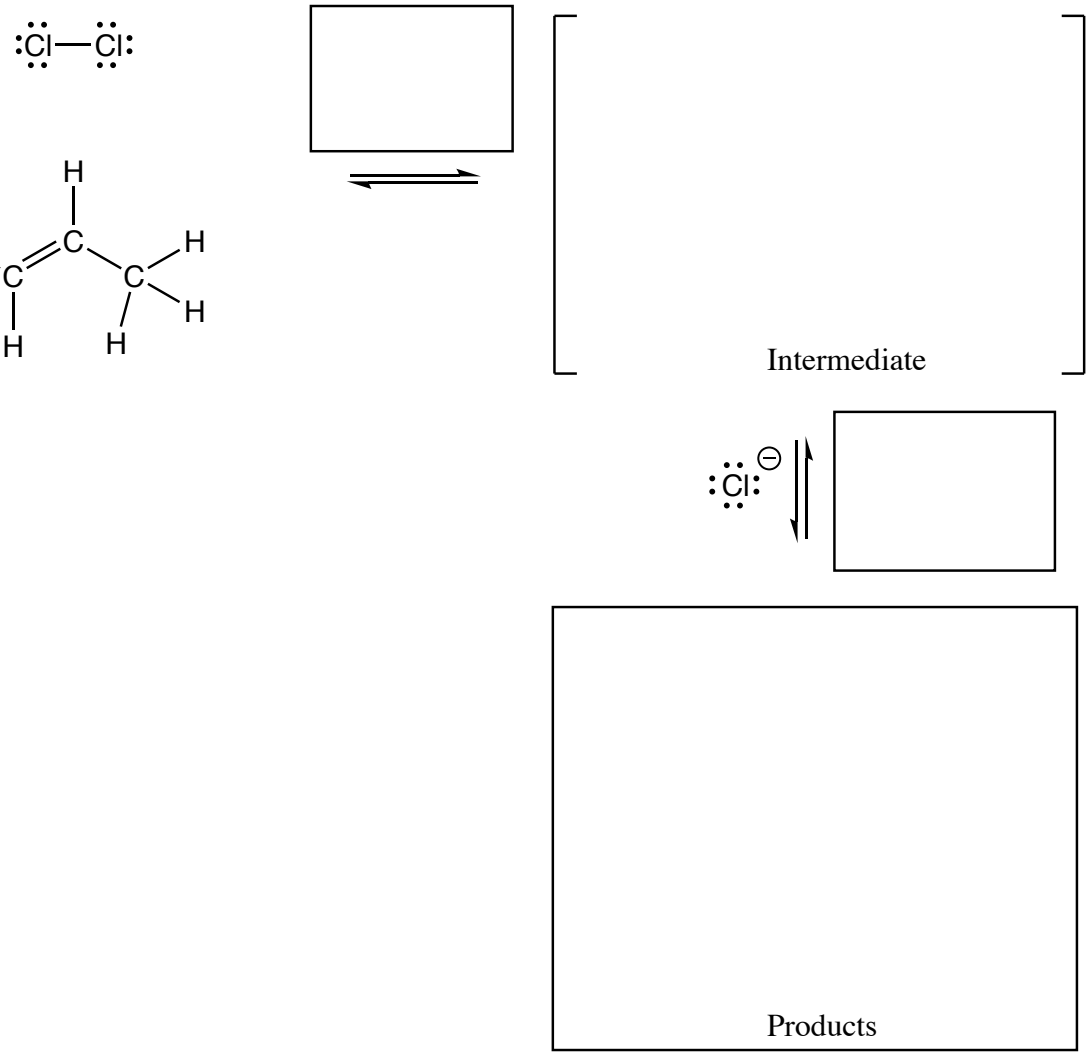
12. (10 pts) Complete the following mechanism for the first step of the hydroboration reaction. Use arrows to indicate the movement of all electrons and be sure to show all electron pairs and formal charges. For this one, we are asking you to draw a transition state. Used dotted lines to indicated any bonds that are being made or broken in the transition state. Indicate any chiral centers with an asterisk (*) and write 'racemic" if appropriate. You only need to draw one stereoisomer of any chiral species. **Note that you should only draw arrows on the structure to the left, not the transition state. NOTICE THE QUESTION AT THE END.**



(4 pts) Look as the energy diagrams on page 9. Write the letter of the one that best describes the mechanism of this reaction.

_____

13. (12 pts) Complete the mechanism for the following alkene halogenation reaction. **Be sure to show arrows to indicate movement of <u>all</u> electrons, write <u>all</u> lone pairs, <u>all</u> formal charges, and <u>all</u> the products for each step.** Remember, I said <u>all</u> the products for each step. **YOU ONLY NEED TO DRAW ONE STEREOISOMER OF A CHIRAL INTERMEDIATE OR PRODUCT (using wedges and dashes as appropriate) IF A NEW CHIRAL CENTER IS CREATED IN AN INTERMEDIATE OR PRODUCT, MARK IT WITH AN ASTERISK AND LABEL THE MOLECULE AS "RACEMIC" IF APPROPRIATE. In the boxes provided, write which of the 4 mechanistic elements describes each step (make a bond, break a bond, etc.). Be sure to notice the questions at the end.**



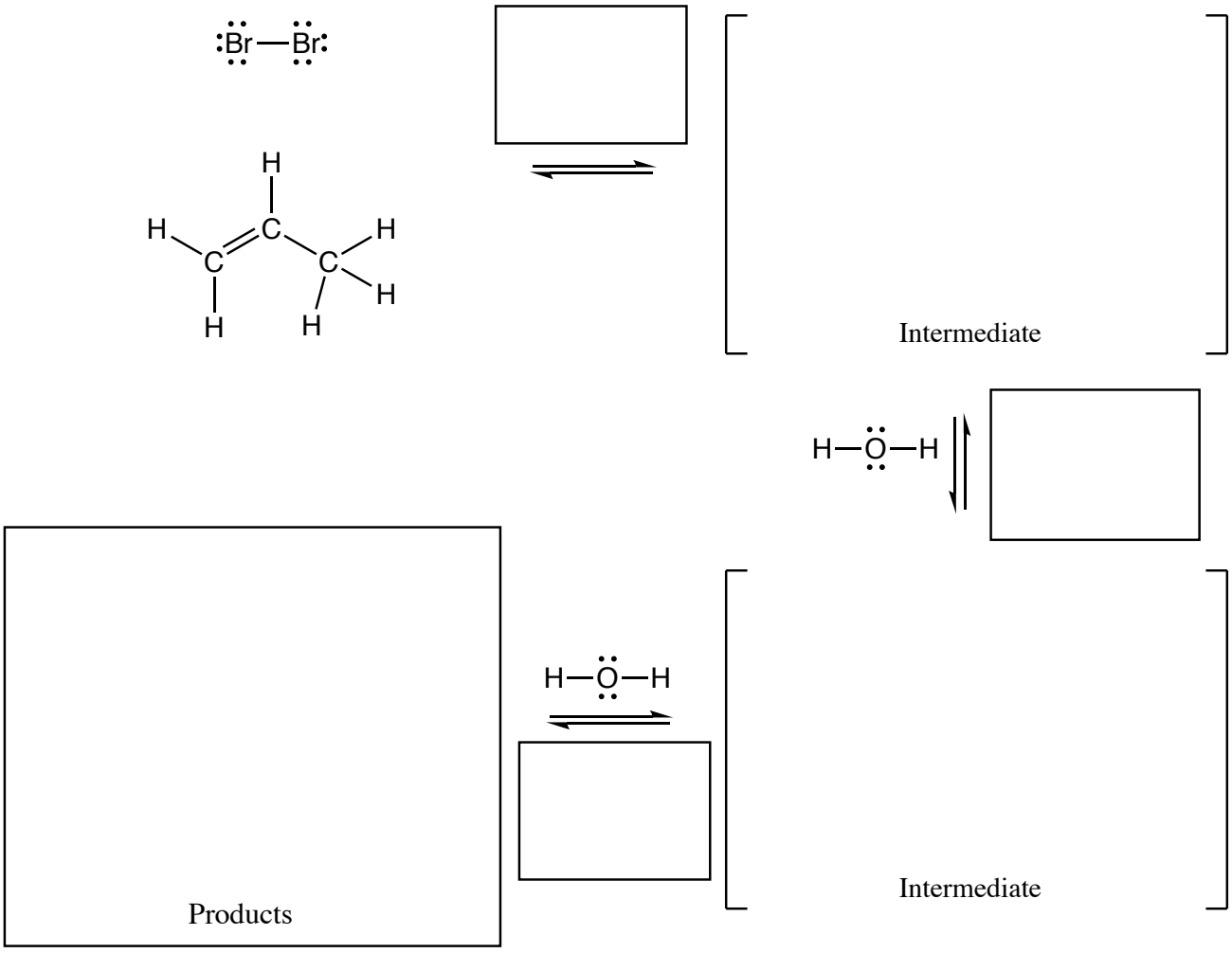
(4 pts) **For any step** in the mechanism on this page that involves a nucleophile reacting with an electrophile to make a bond, **draw a circle around the nucleophile**

(2 pts) How many total stereoisomers are created as the final products? _____

(4 pts) Look as the energy diagrams on page 9. Write the letter of the one that best describes this reaction.

_____

14. (18 pts) Complete the mechanism for the following alkene hydrohalogenation reaction. **Be sure to show arrows to indicate movement of <u>all</u> electrons, write <u>all</u> lone pairs, <u>all</u> formal charges, and <u>all</u> the products for each step.** Remember, I said <u>all</u> the products for each step. **YOU ONLY NEED TO DRAW ONE STEREOISOMER OF A CHIRAL INTERMEDIATE OR PRODUCT (using wedges and dashes as appropriate) IF A NEW CHIRAL CENTER IS CREATED IN AN INTERMEDIATE OR PRODUCT, MARK IT WITH AN ASTERISK AND LABEL THE MOLECULE AS "RACEMIC" IF APPROPRIATE. In the boxes provided, write which of the 4 mechanistic elements describes each step (make a bond, break a bond, etc.). Be sure to notice the questions at the end.**



(4 pts) **For any step** in the mechanism on this page that involves a nucleophile reacting with an electrophile to make a bond, **draw a circle around the nucleophile**

(2 pts) **How many total stereoisomers** are created as the final **products**? _____

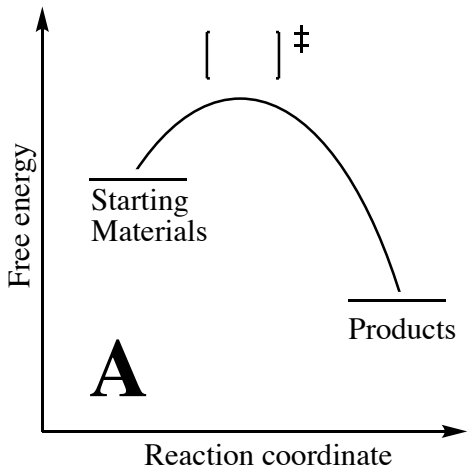
(4 pts) **Look as the energy diagrams on page 9. Write the letter of the one that best describes this reaction.**

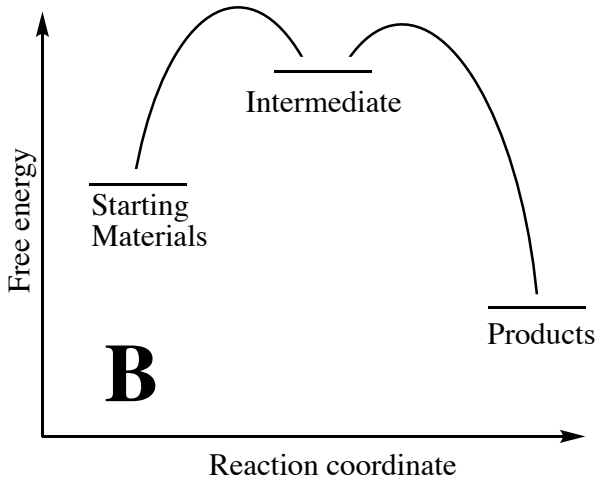
_____

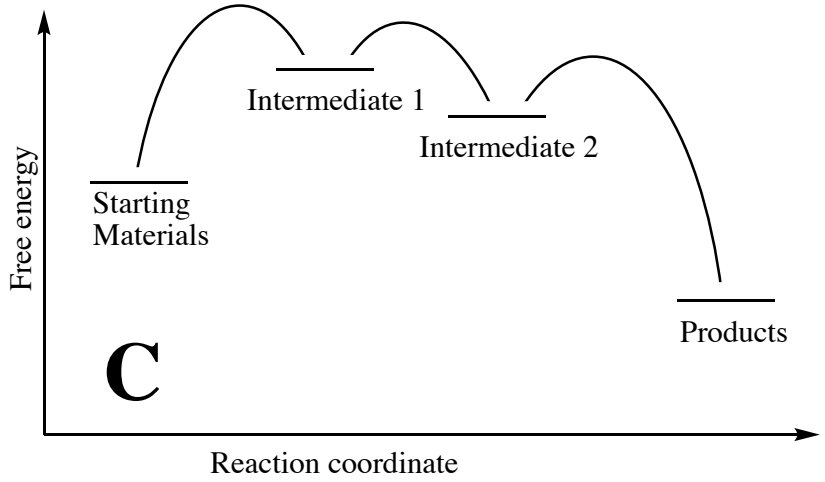
(2 pts) Think about this! As the reaction progresses, does the pH get **higher, lower, or stay the same?**

_____

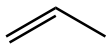
These energy diagrams refer to the mechanisms your completed in problems 12-14 on pages 6-8.

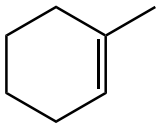


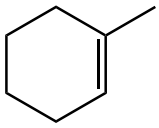


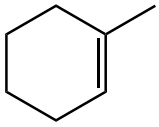


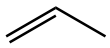
15. (3 or 5 pts each) The following reactions all involve chemistry of alkenes. Fill in the box with the product(s) that are missing from the chemical reaction equations. **Draw only the predominant regioisomer product or products (i.e. Markovnikov or non-Markovnikov products)** and please remember that **you must draw the structures of all the product stereoisomers using wedges and dashes to indicate stereochemistry as appropriate**. When a racemic mixture is formed, **you must write "racemic" under both structures EVEN THOUGH YOU DREW BOTH STRUCTURES**.

A.  $\xrightarrow{Br_2}$

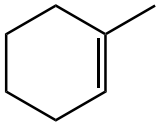
B.  $\xrightarrow[H_2SO_4 \text{ (catalytic amount)}]{H_2O}$

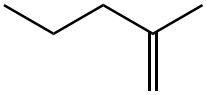
C.  $\xrightarrow[2.\ NaBH_4]{1.\ Hg(OAc)_2 / H_2O}$

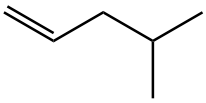
D.  $\xrightarrow[2.\ H_2O_2 / NaOH]{1.\ BH_3}$

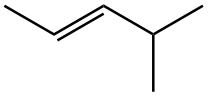
E.  $\xrightarrow[H_2O]{Br_2}$

15. (3 or 5 pts each) The following reactions all involve chemistry of alkenes. Fill in the box with the product(s) that are missing from the chemical reaction equations. **Draw only the predominant regioisomer product or products (i.e. Markovnikov or non-Markovnikov products)** and please remember that **you must draw the structures of all the product stereoisomers using wedges and dashes to indicate stereochemistry when appropriate**. When a racemic mixture is formed, **you must write "racemic" under both structures EVEN THOUGH YOU DREW BOTH STRUCTURES**.

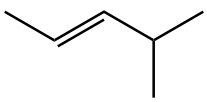
F.  $\xrightarrow[H_2O]{Br_2}$

G.  $\xrightarrow{HCl}$

H.  $\xrightarrow{HI}$

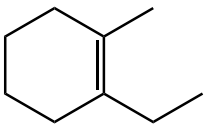
I.  $\xrightarrow{HCl}$

Assume rearrangement and draw the rearranged product only

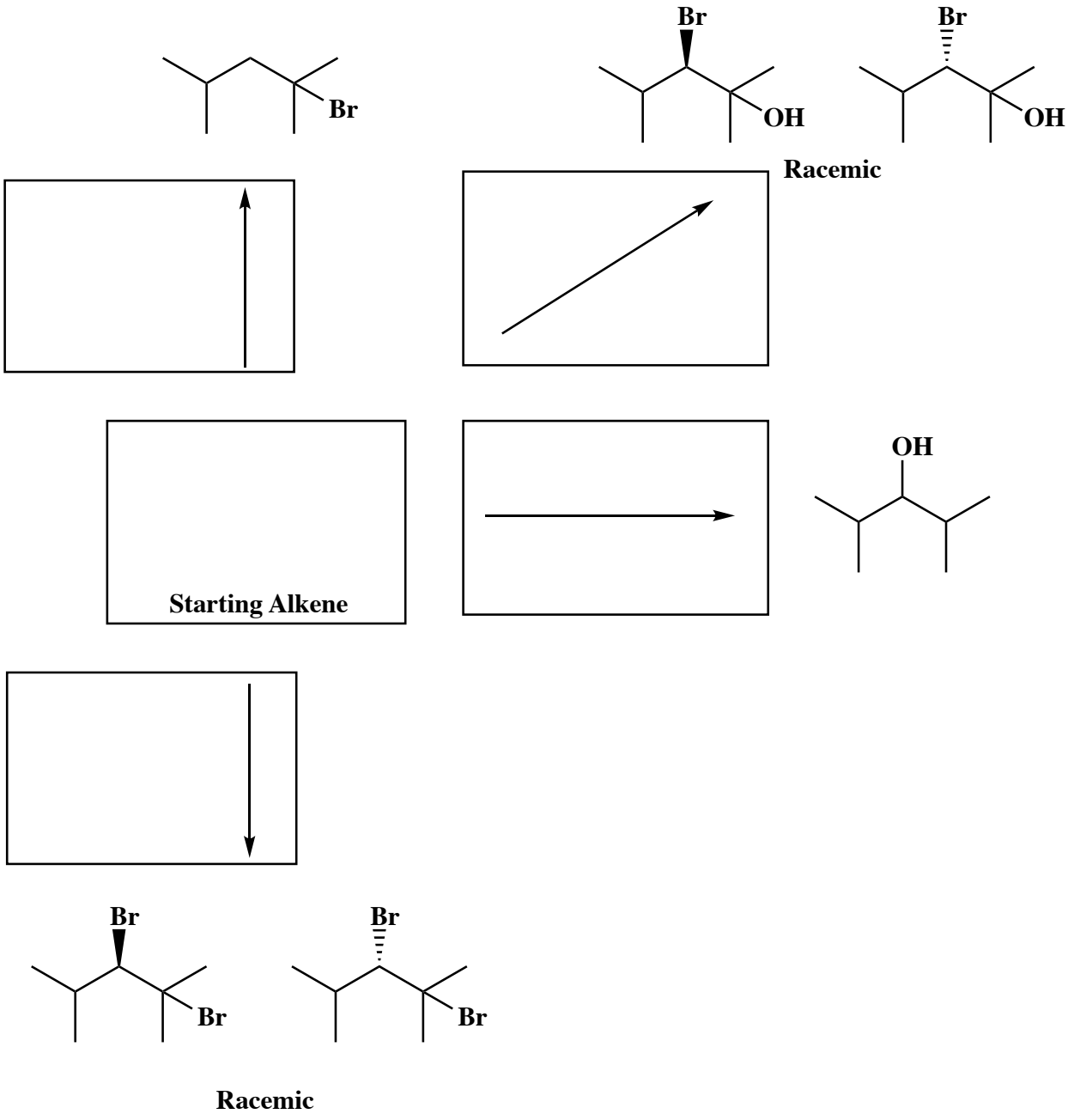
J.  $\xrightarrow{Br_2}$

15. (5 or 10 pts each) The following reactions all involve chemistry of alkenes. Fill in the box with the product(s) that are missing from the chemical reaction equations. **Draw only the predominant regioisomer product or products (i.e. Markovnikov or non-Markovnikov products)** and please remember that **you must draw the structures of all the product stereoisomers using wedges and dashes to indicate stereochemistry as appropriate**. When a racemic mixture is formed, **you must write "racemic" under both structures EVEN THOUGH YOU DREW BOTH STRUCTURES**.

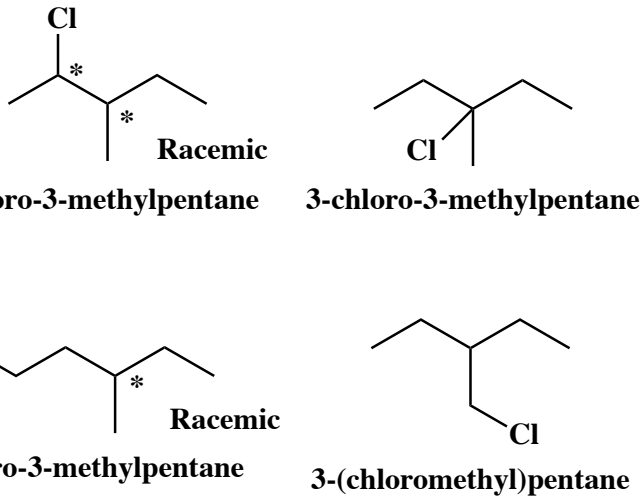
K.  $\xrightarrow{Cl_2}$

L  $\xrightarrow[H_2O]{Br_2}$

16. (16 pts total) Organic chemistry is a very creative science because there are so many different reactions known that often we are only limited by our imaginations. For example, the same starting alkene can be converted to the different products listed. **Deduce the identity of the starting alkene, and write its structure in the box labeled "Starting Alkene". Fill in the boxes containing arrows with the reagents required to produce the given products.**



17. (5 pts) The MCAT and other standard exams are famous for using IUPAC names instead of structures. From the following list, **circle the product of the following reaction.** To make this simpler, we have not used wedges and dashes, but simply designated chiral centers with an asterisk. (Note you are **NOT** allowed to write products in this format on pages 10-12 of this exam, you must use wedges and dashes on those!)



18. (8 pts total) Here is an "apply what you know" question. The reactions we teach in this class are representative examples of entire classes of reactions. Alkenes react with a variety of reagents that are similar to the ones we have discusseed. You have not seen the following two reactions, but use your growing chemical intuition to predict the products for the reactions shown. My only hint is for you to not overthink this, but rely on your understanding of mechanisms to make educated guesses. **The products should be drawn in the same format as for pages 10-12 of this exam.**

Save this one until last! I have given you the products, you need to draw the starting material