NAME (Print): _____

SIGNATURE: _____

Chemistry 320M/328M
Dr. Brent Iverson
3rd Midterm
November 16, 2017

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

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

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

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

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

Page	Points	
1		**(33)**
2		**(27)**
3		**(24)**
4		**(19)**
5		**(28)**
6		**(19)**
7		**(26)**
8		**(23)**
9		**(20)**
10		**(21)**
11		**(25)**
12		**(24)**
13		**(10)**
Total		**(299)**

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

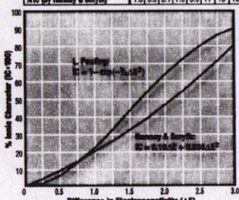
▼ Elementary Subatomic Particles

	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	5.44617013(11) x 10^{-4}	1	1.001378404(9)	0	≈ 0
Particle-neutron mass ratio	5.438673x10^{-4}	0.998624	1	0	≈ 0
Specific charge (C/kg)	−1.7588196(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)	2.42631058(22) x 10^{-12}	1.3214100(12) x 10^{-15}	1.3195910(12) x 10^{-15}	–	–
Magnetic moment (μ/T); μ	928.47701(31) x 10^{-26}	1.41060761(47) x 10^{-26}	0.96623707(40) x 10^{-26}	0	0
In Bohr magnetons; μ_l/μ_B	1.001159652193(10)	1.5210322(25) x 10^{-3}	1.0416736(25) x 10^{-3}	0	0
In nuclear magnetons; μ_l/μ_N	1838.282000(37)	2.79284739(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 the 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 = 5.0507699(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	69	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 0
1.00794 -259.34 -252.87 0.0899 2.20 13.598 $1s^1$ **1 H** Hydrogen	2 IIA											13 IIIB IIIA	14 IVB IVA	15 VB VA	16 VIB VIA	17 VIIB VIIA	4.0026022 -272.2 (5 atm) -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 – 2.31 8.296 $[He]2s^22p^1$ **5 B** Boron	12.011 4492* 3825* 2.25 2.55 11.260 $[He]2s^22p^2$ **6 C** Carbon 2,±4	14.00674 -210.00 -195.79 1.25046 3.04 14.534 $[He]2s^22p^3$ **7 N** Nitrogen 2,±3,±4,5	15.9994 -218.79 -182.95 1.429 3.44 13.618 $[He]2s^22p^4$ **8 O** Oxygen -2	18.9984032 -219.62 -188.12 1.69 3.98 17.422 $[He]2s^22p^5$ **9 F** Fluorine -1	20.1797 -248.59 -185.85 1.784 – 15.759 $[He]2s^22p^6$ **10 Ne** Neon 0
22.989768 97.72 883 0.97 0.93 5.139 $[Ne]3s^1$ **11 Na** Sodium 1	24.3050 650 1090 1.74 1.31 7.646 $[Ne]3s^2$ **12 Mg** Magnesium 2	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	26.981539 660.32 2519 2.702 1.61 5.986 $[Ne]3s^23p^1$ **13 Al** Aluminum 3	28.0855 1414 3265 2.33 1.90 8.151 $[Ne]3s^23p^2$ **14 Si** Silicon 4	30.973762 44.15 277 1.82 2.19 10.486 $[Ne]3s^23p^3$ **15 P** Phosphorus ±3,±5	32.066 115.21 444.60 2.07 2.58 10.360 $[Ne]3s^23p^4$ **16 S** Sulfur ±2,4,6	35.4527 -101.5 -34.04 3.214 3.16 12.967 $[Ne]3s^23p^5$ **17 Cl** Chlorine ±1,3,5,7	39.948 -189.35 -185.85 1.784 – 15.759 $[Ne]3s^23p^6$ **18 Ar** Argon 0
39.0983 63.38 759 0.86 0.82 4.341 $[Ar]4s^1$ **19 K** Potassium 1	40.078 842 1484 1.54 1.00 6.113 $[Ar]4s^2$ **20 Ca** Calcium 2	44.955910 1541 2830 2.989 1.36 6.54 $[Ar]3d^14s^2$ **21 Sc** Scandium 3	47.88 1668 3287 4.5 1.54 6.82 $[Ar]3d^24s^2$ **22 Ti** Titanium 2,3,4	50.9415 1910 3407 5.96 1.63 8.74 $[Ar]3d^34s^2$ **23 V** Vanadium 2,3,4,5	51.9961 1907 2671 7.20 1.66 8.766 $[Ar]3d^54s^1$ **24 Cr** Chromium 2,3,6	54.93805 1246 2061 7.47 1.55 7.435 $[Ar]3d^54s^2$ **25 Mn** Manganese 2,3,4,6,7	55.847 1538 2861 7.86 1.83 7.870 $[Ar]3d^64s^2$ **26 Fe** Iron 2,3	58.93320 1495 2927 8.92 1.88 7.86 $[Ar]3d^74s^2$ **27 Co** Cobalt 2,3	58.6934 1455 2913 8.90 1.91 7.635 $[Ar]3d^84s^2$ **28 Ni** Nickel 2,3	63.546 1084.62 2562 8.94 1.90 7.726 $[Ar]3d^{10}4s^1$ **29 Cu** Copper 1,2	65.39 419.53 907 7.14 (20°C) 1.65 9.394 $[Ar]3d^{10}4s^2$ **30 Zn** Zinc 2	69.723 29.76 2204 5.095 1.81 5.999 $[Ar]3d^{10}4s^24p^1$ **31 Ga** Gallium 3	72.61 938.25 2833 5.35 2.01 7.899 $[Ar]3d^{10}4s^24p^2$ **32 Ge** Germanium 4	74.92159 817* (14* atm) 5.727 (20°C) 2.18 0.81 [Ar]3d^{10}4s^24p^3 **33 As** Arsenic ±3,5	78.96 221 685 4.81 2.55 9.752 $[Ar]3d^{10}4s^24p^4$ **34 Se** Selenium -2,4,6	79.904 -7.2 58.8 3.119 2.96 11.814 $[Ar]3d^{10}4s^24p^5$ **35 Br** Bromine ±1,5	83.80 -157.36 -153.22 3.74 – 13.999 $[Ar]3d^{10}4s^24p^6$ **36 Kr** Krypton 0
85.4678 38.31 688 1.532 0.82 4.177 $[Kr]5s^1$ **37 Rb** Rubidium 1	87.62 777 1382 2.6 0.95 5.866 $[Kr]5s^2$ **38 Sr** Strontium 2	88.90585 1526 3336 4.469 1.22 6.38 $[Kr]4d^15s^2$ **39 Y** Yttrium 3	91.224 1855 4409 6.49 1.33 6.84 $[Kr]4d^25s^2$ **40 Zr** Zirconium 4	92.90638 2477 4744 8.57 1.6 6.9 $[Kr]4d^45s^1$ **41 Nb** Niobium 3,5	95.94 2623 4639 10.2 2.16 7.099 $[Kr]4d^55s^1$ **42 Mo** Molybdenum 2,3,4,5,6	(97.9072) 2157 4265 11.5 1.9 7.28 $[Kr]4d^55s^2$ **43 Tc** Technetium 7	101.07 2334 4150 12.3 2.2 7.37 $[Kr]4d^75s^1$ **44 Ru** Ruthenium 2,3,4,6,8	102.90550 1964 3695 12.4 2.28 7.46 $[Kr]4d^85s^1$ **45 Rh** Rhodium 2,3,4	106.42 1554.9 2963 12.02 2.20 8.34 $[Kr]4d^{10}$ **46 Pd** Palladium 2,4	107.8682 961.78 2162 10.5 1.93 7.576 $[Kr]4d^{10}5s^1$ **47 Ag** Silver 1,2	112.411 321.07 767 8.642 1.69 8.993 $[Kr]4d^{10}5s^2$ **48 Cd** Cadmium 2	114.818 156.60 2072 7.30 1.78 5.786 $[Kr]4d^{10}5s^25p^1$ **49 In** Indium 3	118.710 231.93 2833 7.28 1.96 7.344 $[Kr]4d^{10}5s^25p^2$ **50 Sn** Tin 2,4	121.757 630.63 1587 6.684 (20°C) 2.05 8.641 $[Kr]4d^{10}5s^25p^3$ **51 Sb** Antimony ±3,5	127.60 449.51 988 6.25 2.1 9.009 $[Kr]4d^{10}5s^25p^4$ **52 Te** Tellurium -2,4,6	126.90447 113.7 184.4 4.93 2.66 10.451 $[Kr]4d^{10}5s^25p^5$ **53 I** Iodine ±1,5,7	131.29 -111.75 -108.04 5.89 – 12.130 $[Kr]4d^{10}5s^25p^6$ **54 Xe** Xenon 0
132.90543 28.44 671 1.879 0.79 3.894 $[Xe]6s^1$ **55 Cs** Cesium 1	137.327 727 1897 3.594 0.89 5.212 $[Xe]6s^2$ **56 Ba** Barium 2	138.9055 920 3455 6.146 1.10 5.577 $[Xe]5d^16s^2$ **57 La** Lanthanum 3	178.49 2233 4603 13.31 1.3 7.0 $[Xe]4f^{14}5d^26s^2$ **72 Hf** Hafnium 4	180.9479 3017 5458 16.6 1.5 7.89 $[Xe]4f^{14}5d^36s^2$ **73 Ta** Tantalum 5	183.84 3422 5555 19.35 2.36 7.98 $[Xe]4f^{14}5d^46s^2$ **74 W** Tungsten 2,3,4,5,6	186.207 3186 5596 20.5 1.9 7.88 $[Xe]4f^{14}5d^56s^2$ **75 Re** Rhenium −1,2,4,6,7	190.23 3033 5012 22.61 2.2 8.7 $[Xe]4f^{14}5d^66s^2$ **76 Os** Osmium 2,3,4,6,8	192.22 2446 4428 22.65 2.20 9.1 $[Xe]4f^{14}5d^76s^2$ **77 Ir** Iridium 2,3,4,6	195.08 1768.4 3825 21.45 2.28 9.0 $[Xe]4f^{14}5d^96s^1$ **78 Pt** Platinum 2,4	196.96654 1064.18 2856 19.31 2.54 9.225 $[Xe]4f^{14}5d^{10}6s^1$ **79 Au** Gold 1,3	200.59 -38.83 356.72 13.546 2.00 10.437 $[Xe]4f^{14}5d^{10}6s^2$ **80 Hg** Mercury 1,2	204.3833 304 1473 11.85 2.04 6.108 $[Xe]4f^{14}5d^{10}6s^26p^1$ **81 Tl** Thallium 1,3	207.2 327.46 1749 11.34 2.33 7.416 $[Xe]4f^{14}5d^{10}6s^26p^2$ **82 Pb** Lead 2,4	208.98037 271.40 1564 9.78 2.02 7.289 $[Xe]4f^{14}5d^{10}6s^26p^3$ **83 Bi** Bismuth 3,5	(208.9824) 254 962 9.196 2.0 8.42 $[Xe]4f^{14}5d^{10}6s^26p^4$ **84 Po** Polonium 2,4	(209.9871) 302 337 – 2.2 – $[Xe]4f^{14}5d^{10}6s^26p^5$ **85 At** Astatine ±1,3,5,7	(222.0176) -71 -61.7 9.73 – 10.748 $[Xe]4f^{14}5d^{10}6s^26p^6$ **86 Rn** Radon 0
(223.0197) 27 677 – 0.7 – $[Rn]7s^1$ **87 Fr** Francium 1	(226.0254) 700 <1140 5.0 0.9 5.279 $[Rn]7s^2$ **88 Ra** Radium 2	(227.0278) 1051 3198 10.07 1.1 6.9 $[Rn]6d^17s^2$ **89 Ac** Actinium •• 3	(261.11) – – – – – $[Rn]5f^{14}6d^27s^2$ **104 Unq** Unnilquadium 4	(262.114) – – – – – $[Rn]5f^{14}6d^37s^2$ **105 Unp** Unnilpentium	(263.118) – – – – – $[Rn]5f^{14}6d^47s^2$ **106 Unh** Unnilhexium	(262.12) – – – – – $[Rn]5f^{14}6d^57s^2$ **107 Uns** Unnilseptium	(265) – – – – – $[Rn]5f^{14}6d^67s^2$ **108 Uno** Unniloctium	(266) – – – – – $[Rn]5f^{14}6d^77s^2$ **109 Une** Unnilennium	(272) – – – – – $[Rn]5f^{14}6d^{10}7s^1$ **110 Uun** Ununnium								

*indicates approximate values and/or inconsistent literature data.

7 VIIA VIIB
54.93805 1246 2061 7.47 1.55 7.435 $[Ar]3d^54s^2$ **25 Mn** Manganese 2,3,4,6,7

Atomic Weight[1] (() indicates most stable or best known isotope)
Melting Point[7], °C
Boiling Point[7], °C
Density[4], g/cm³ (gases: g/L at 0°C, 1 atm)
Electronegativity[8]
First Ionization Potential[10], eV
Group Classifications[6]
Atomic Number[2]
Oxidation States[3] (bold indicates most stable state)
Symbol[4] (black = solid, red = gas, blue = liquid, outline = synthetically prepared)
Electronic Configuration[5]
Name[4]

140.115 798 3424 6.710 1.12 5.466 $[Xe]4f^15d^16s^2$ **58 Ce** Cerium 3,4	140.90765 931 3510 6.773 1.13 5.42 $[Xe]4f^36s^2$ **59 Pr** Praseodymium 3,4	144.24 1016 3066 7.00 1.14 5.489 $[Xe]4f^46s^2$ **60 Nd** Neodymium 3	(144.9127) 1042 3000 7.264 1.13 5.554 $[Xe]4f^56s^2$ **61 Pm** Promethium 3	150.36 1072 1700 7.536 1.17 5.631 $[Xe]4f^66s^2$ **62 Sm** Samarium 2,3	151.965 822 1596 5.244 1.2 5.666 $[Xe]4f^76s^2$ **63 Eu** Europium 2,3	157.25 1314 3264 7.901 1.20 6.141 $[Xe]4f^75d^16s^2$ **64 Gd** Gadolinium 3	158.92534 1359 3221 8.230 1.2 5.842 $[Xe]4f^96s^2$ **65 Tb** Terbium 3,4	162.50 1411 2561 8.551 1.22 5.927 $[Xe]4f^{10}6s^2$ **66 Dy** Dysprosium 3	164.93032 1472 2694 8.80 1.23 6.018 $[Xe]4f^{11}6s^2$ **67 Ho** Holmium 3	167.26 1529 2862 9.066 1.24 6.101 $[Xe]4f^{12}6s^2$ **68 Er** Erbium 3	168.93421 1545 1946 9.321 1.25 6.18436 $[Xe]4f^{13}6s^2$ **69 Tm** Thullium 2,3	173.04 824 1194 6.966 1.1 6.25394 $[Xe]4f^{14}6s^2$ **70 Yb** Ytterbium 2,3	174.967 1663 3393 9.84 1.27 5.42589 $[Xe]4f^{14}5d^16s^2$ **71 Lu** Lutetium 3
232.0381 1750 4788 11.72 1.3 6.08 $[Rn]6d^27s^2$ **90 Th** Thorium 4	231.03588 1572 – 15.37 1.5 5.89 $[Rn]5f^26d^17s^2$ **91 Pa** Protactinium 4,5	238.0289 1135 4131 19.05±0.02 1.38 6.05 $[Rn]5f^36d^17s^2$ **92 U** Uranium 3,4,5,6	(237.0482) 644 3909 20.45 1.36 6.19 $[Rn]5f^46d^17s^2$ **93 Np** Neptunium 3,4,5,6,7	(244.0642) 640 3228 19.816 1.28 5.8 $[Rn]5f^67s^2$ **94 Pu** Plutonium 3,4,5,6	(243.0614) 1176 2607 13.67 1.3 5.993 $[Rn]5f^77s^2$ **95 Am** Americium 3,4,5,6	(247.0703) 1345 – 13.51 1.3 6.02 $[Rn]5f^76d^17s^2$ **96 Cm** Curium 3	(247.0703) 1050 – 14.78 1.3 6.23 $[Rn]5f^97s^2$ **97 Bk** Berkelium 3,4	(251.0796) 900 – – 1.3 6.30 $[Rn]5f^{10}7s^2$ **98 Cf** Californium 3	(252.083) 860 – – 1.3 6.42 $[Rn]5f^{11}7s^2$ **99 Es** Einsteinium 3	(257.0951) 1527 – – 1.3 6.50 $[Rn]5f^{12}7s^2$ **100 Fm** Fermium 3	(258.10) 827 – – 1.3 6.58 $[Rn]5f^{13}7s^2$ **101 Md** Mendelevium 2,3	(259.1009) 827 – – 1.3 6.65 $[Rn]5f^{14}7s^2$ **102 No** Nobelium 2,3	(262.11) 1627 – – – – $[Rn]5f^{14}6d^17s^2$ **103 Lr** Lawrencium 3

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

1. Ratio of the average mass per atom of the element to 1/12 of the mass of an atom of ^{12}C. Round brackets indicate atomic weight of the most stable or best known isotope. **2.** Number of protons in the nucleus of each atom of an element. **3.** Number of charges an atom would have in a molecule (or an ionic compound) if electrons were transferred completely. **4.** Names and symbols of elements 104-110 are those recommended by the International Union of Pure and Applied Chemistry (IUPAC)—alternative names have been proposed by other groups. **5.** Distribution of electrons among the various atomic orbitals. **6.** Two older group classifications systems still in use today rely on an A/B scaling scheme to categorize periodic properties. Because of the potential for confusion between these two systems (i.e., IIIA in one scheme is equal to VIIB 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).

PAPERTECH

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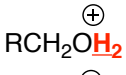
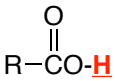
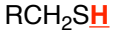
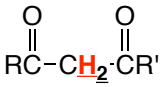
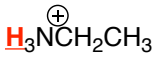
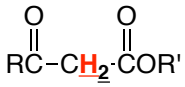
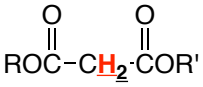
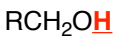
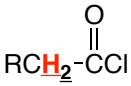
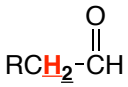
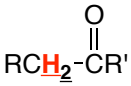
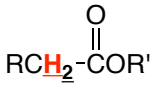
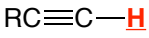
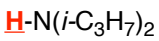
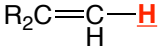
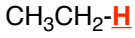
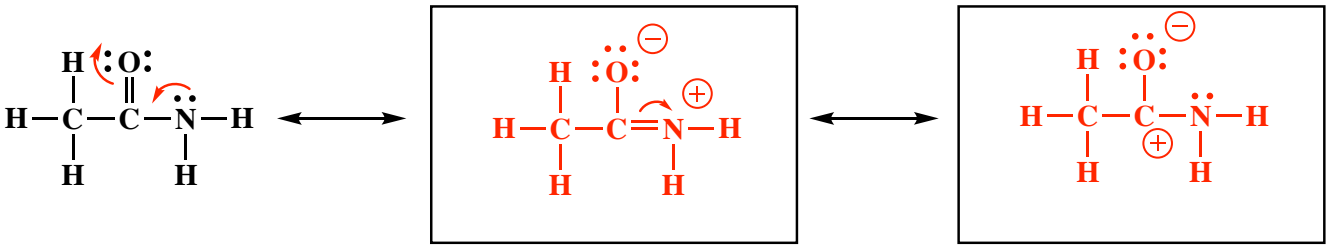
Compound		pK_a
Hydrochloric acid		-7
Protonated alcohol		-2
Hydronium ion		-1.7
Carboxylic acids		3-5
Thiols		8-9
Ammonium ion		9.2
β-Dicarbonyls		10
Primary ammonium		10.5
β-Ketoesters		11
β-Diesters		13
Water		15.7
Alcohols		15-19
Acid chlorides		16
Aldehydes		18-20
Ketones		18-20
Esters		23-25
Terminal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

Signature_____ Pg 1 _____(33)

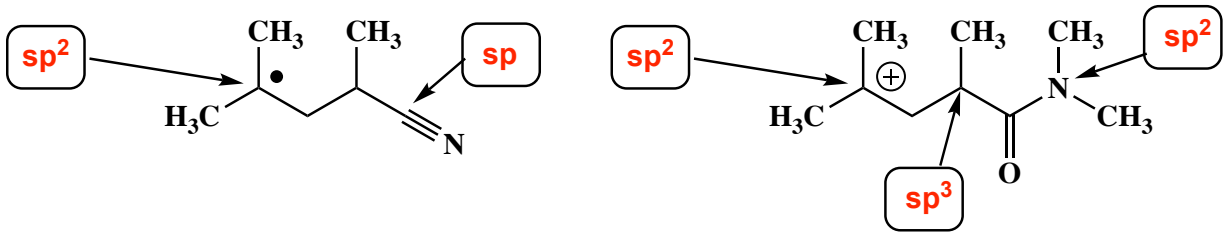
1. (5 pts) What is the most important question in organic chemistry?

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

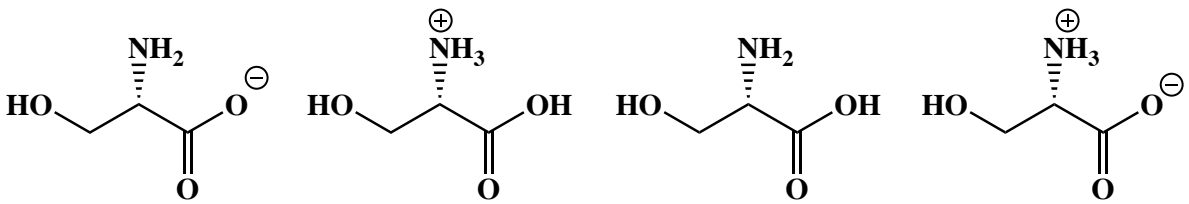


3. (10 pts.) On the following structures, indicate the hybridization state of each atom indicated with an arrow



4. (8 pts.) Put a 2 under the species that will be the predominant one present at pH 2.0, put a 7 under the species that will be the predominant one present at pH 7.0, put a 12 under the species that will be the predominant one present at pH 12.0 and **put an "X" under a species that cannot predominant at any pH.**

The pKa of a carboxylic acid (RCO_2H) is generally in the 4-5 range. The pKa of ammonium ions ($RNH_3^{\oplus}$) is in the 9-10 range.



12 2 X 7

5. (16 pts) Fill in each blank with the word that best completes each sentence

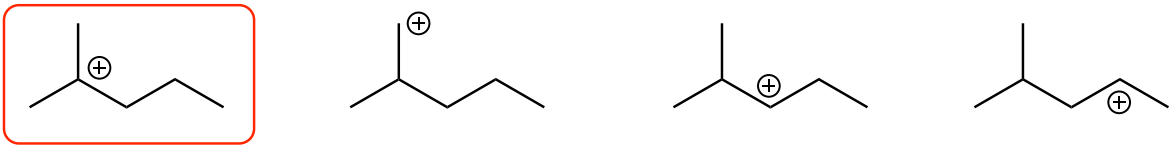
The ___Hammond___ postulate, i.e. transition states resemble more closely the structures of the species they are closest to in ___energy___, explains why ___bromination___ is more selective than chlorination. Bottom line: Always use ___Br_2___ and light when reacting alkanes to give haloalkanes.

The ___enol___ form of a compound rapidly ___tautomerizes___ to the more stable keto form. The keto form is more stable because the ___C=O___ pi bond is stronger than the ___C=C___ pi bond

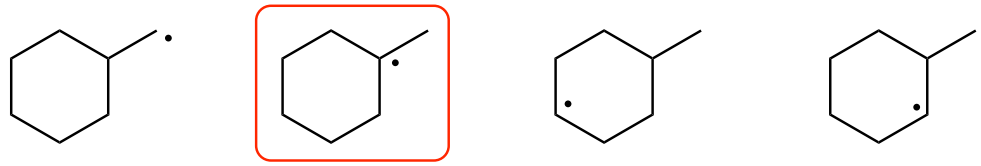
6. (11 pts) Consider the following statements that refer **S_N1, S_N2, E1, E2**, or a **radical chain reaction** meachanism. To which mechanism(s), if any, does each statement apply?

	Mechanism(s)
A. The reaction(s) that involves an InVERSiON of stereochemistry at the site of reaction.	**S_N2**
B. The reaction(s) that involves a carbocation intermediate.	**S_N1, E1**
C. The reaction(s) that involves an anti-periplanar transition state.	**E2**
D. This reaction mechanism can be triggered by using light of the appropriate wavelength or heat.	**radical chain reaction**
E. Favored for tertiary haloalkanes when weak nucleophiles/weak bases are used.	**S_N1, E1**
F. Favored for primary haloalkanes when any nucleophile is used.	**S_N2**
G. Favored for secondary haloalkanes when a nucleophile that is also a strong base is used.	**E2**
H. The reaction(s) in which the predominant product is predicted by Zaitsev's rule.	**E2, E1**

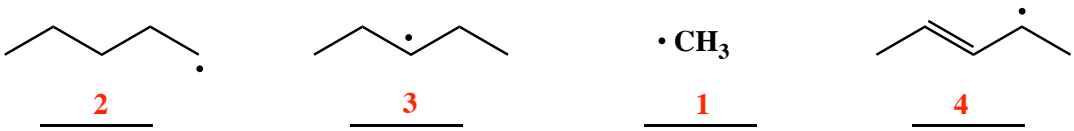
7. (4 pts) For the following series of carbocations, **circle the most stable carbocation.**



8. (4 pts) For the following series of radicals, **circle the most stable radical.**

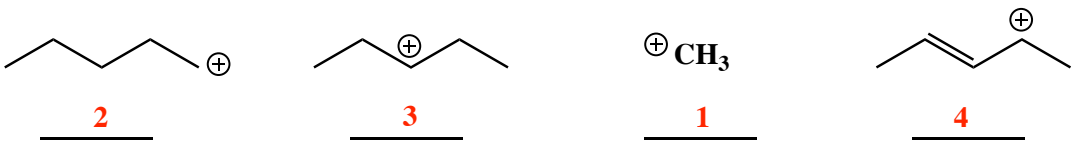


9A. (4 pts) **Rank the following from 1-4** with respect to radical stability, with the **1 under the least stable radical** and the **4 under the most stable radical.**



2 3 1 4

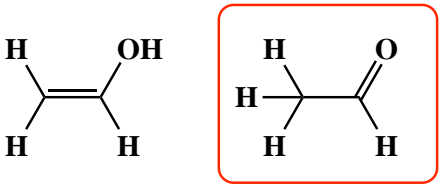
9B. (4 pts) **Rank the following from 1-4** with respect to carbocation stability, with the **1 under the least stable carbocation** and the **4 under the most stable carbocation.**



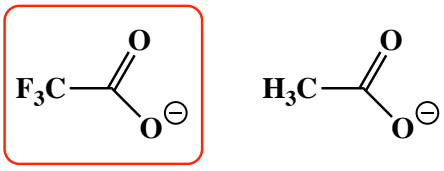
2 3 1 4

10. (8 pts) For each pair of molecules, **circle the one that is more stable** (lower in energy)

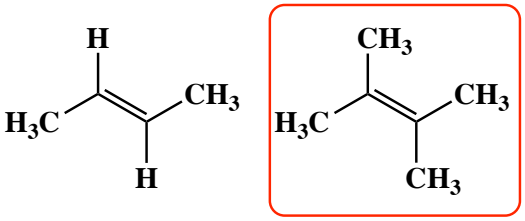
A)



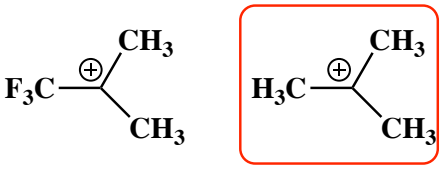
B)



C)



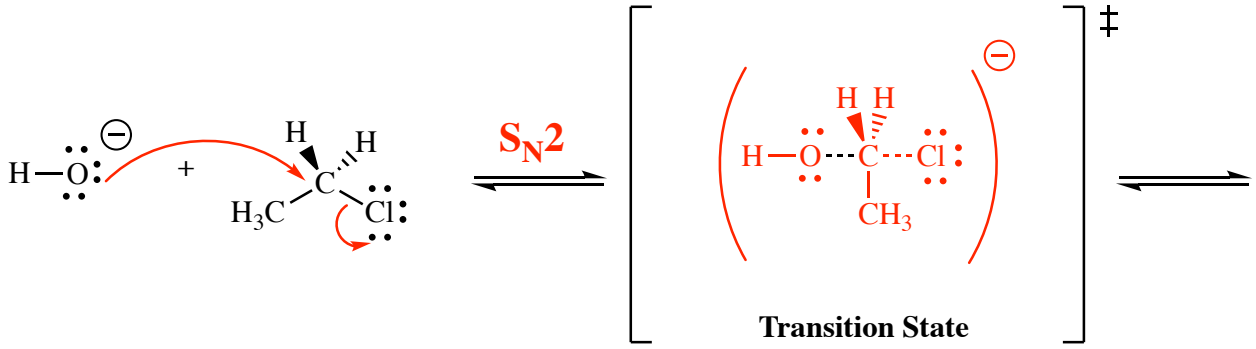
D)



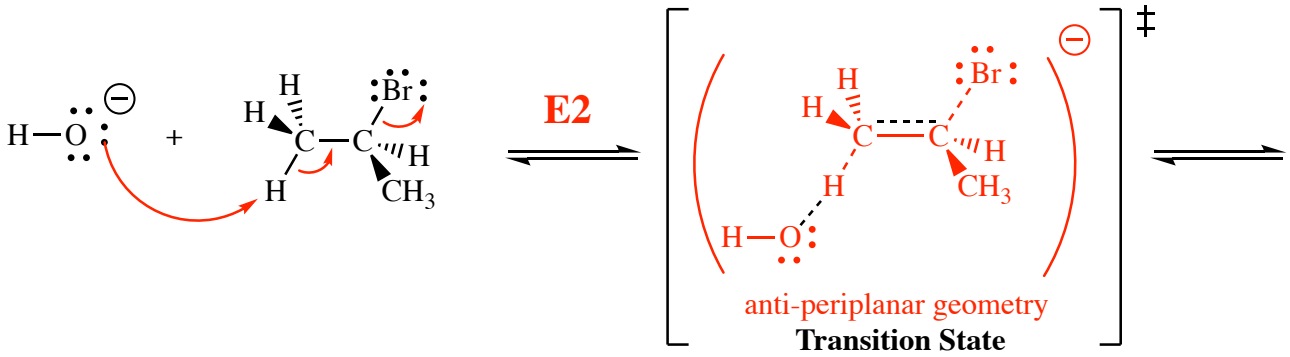
11. (13 pts total) For each reaction below, draw the indicated **key transition state**. We do not want the entire mechanism or products, just the first key transition state. **Use dotted lines to indicate bonds that are in the process of being broken or made. Write all formal charges. On the starting structures, draw all appropriate arrows to indicate the flow of electrons.**

----- Bond being formed
----- Bond being broken

A.

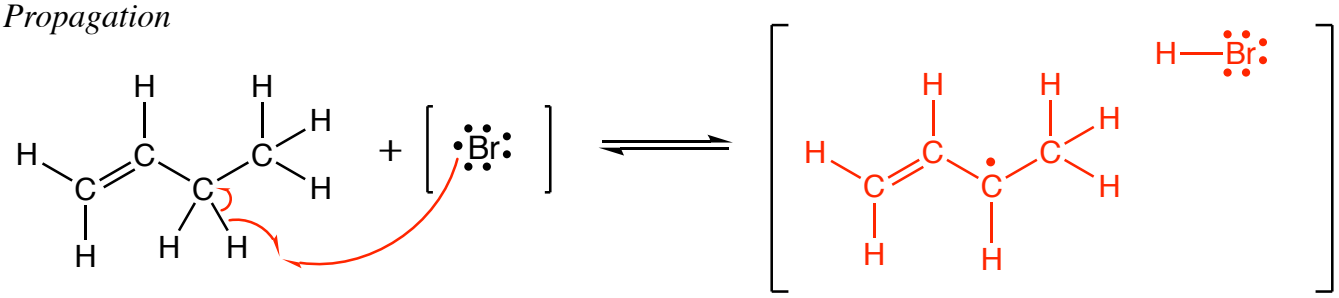


B.



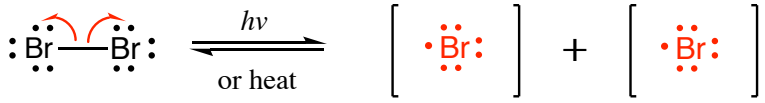
12. (6 pts total) For the reagents below, draw the **first key intermediate** that occurs during the allylic halogenation of an alkene reaction that uses NBS and light. We do not want the entire mechanism or products, just the first key intermediate in the propagation step. **Write all formal charges. On the starting structures, draw all appropriate arrows to indicate the flow of electrons.**

Propagation

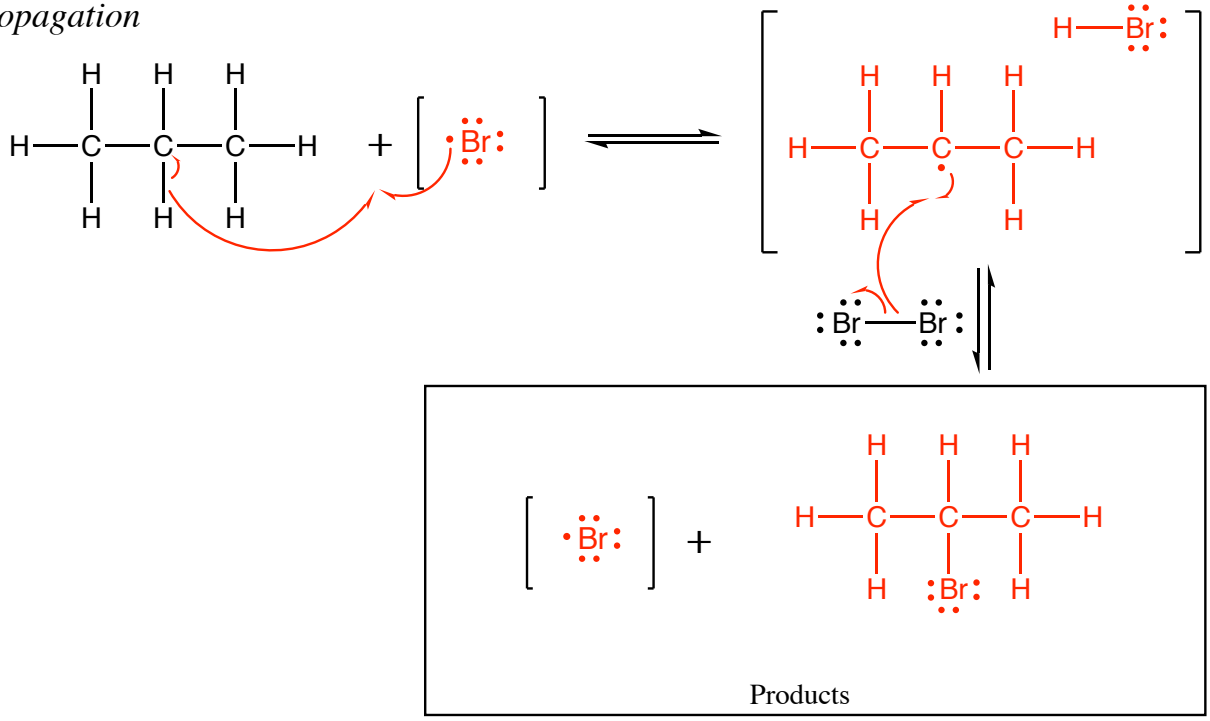


13. (28 pts total) Complete the following mechanism for the halogenation of an alkane. Use appropriate arrows to show movement of electron density, and show all non-bonding electrons as dots and show any formal charges. **If any of the species are really a racemic mixtures of enantiomers, you only need to draw one stereoisomer and write "racemic". Note that for the termination step, you only need to draw one of the three possible examples of termination.**

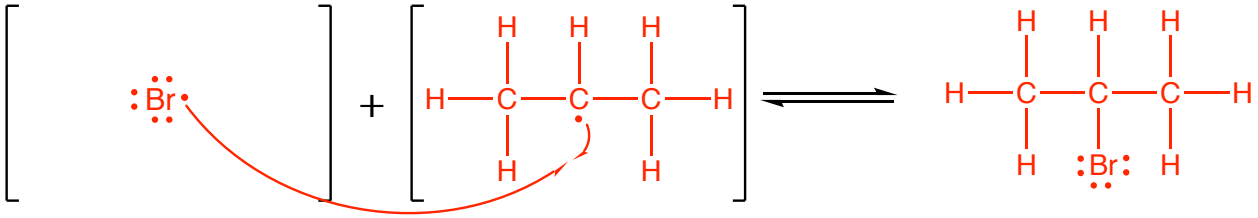
Initiation



Propagation

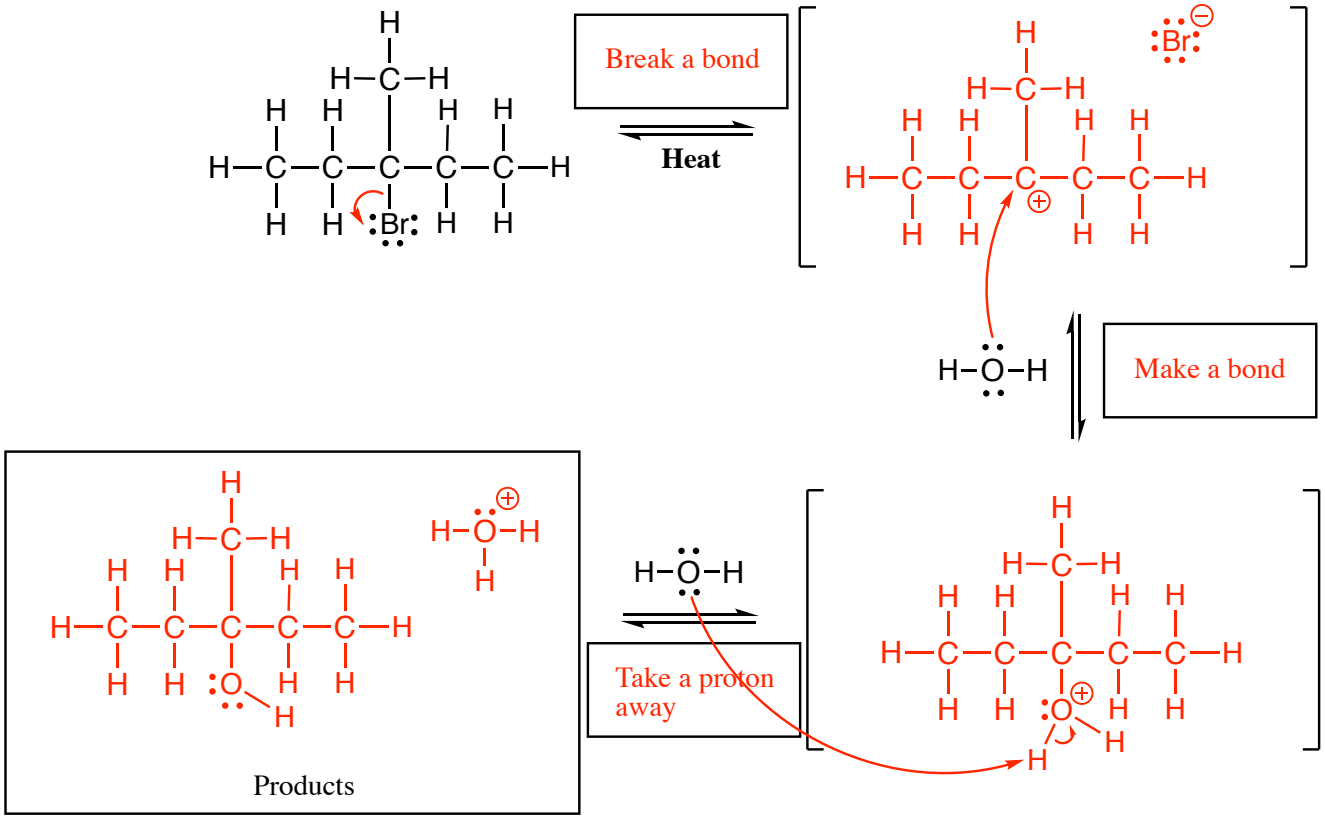


Termination (You only need to show one of the three possible termination steps)



Any combination of these two radicals is correct for an example of a termination step

14. (19 pts total) Complete the following mechanism for an S_N1 reaction. Note that to keep this simple, you do NOT have to show the E1 reaction that would accompany this one. Use appropriate arrows to show movement of electron density, and show all non-bonding electrons as dots and show any formal charges. **If any of the species are really a racemic mixtures of enantiomers, you only need to draw one stereoisomer and write "racemic". In the boxes provided next to the arrows, list the mechanistic element that best describes each step ("make a bond", "break a bond", etc.) NOTICE THE QUESTIONS AT THE BOTTOM.**



As the reaction shown above proceeds, does the pH remain the same, get lower or get higher with time?

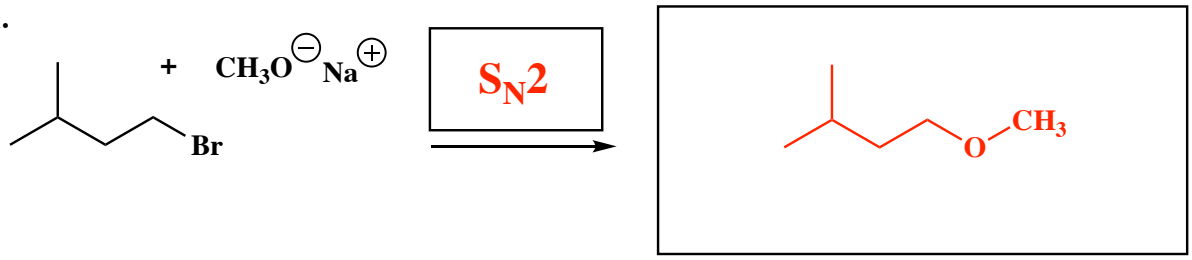
It gets lower (acid is produced)

Does the rate-limiting step of this reaction involve only the haloalkane, or both the haloalkane and the H_2O?

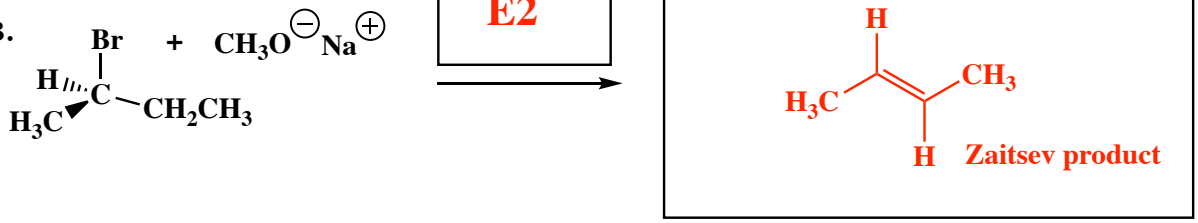
Only the haloalkane (the bond breaking step is slowest and therefore rate-limiting)

16. (5 or 6 pts each) The following reactions all involve chemistry of haloalkanes. **Fill in the box above the arrow with the mechanism that will be followed (S_N2, E2, etc.). Then draw only the predominant product or products** and please remember that **you must draw the correct stereoisomers**. For S_N1/E1 reactions you must draw all significant products (including all stereoisomers).

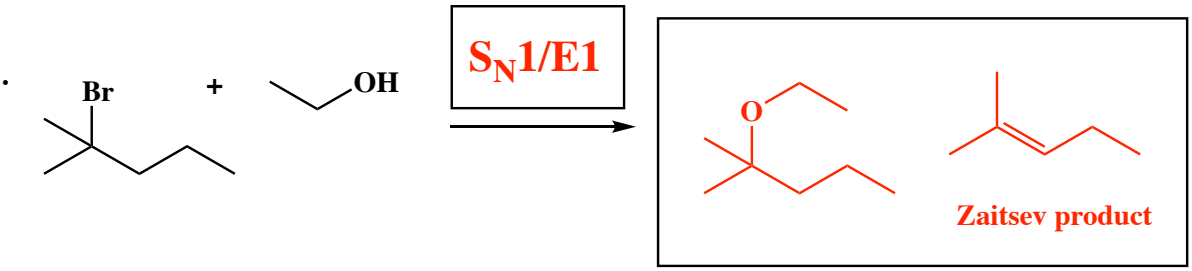
A.



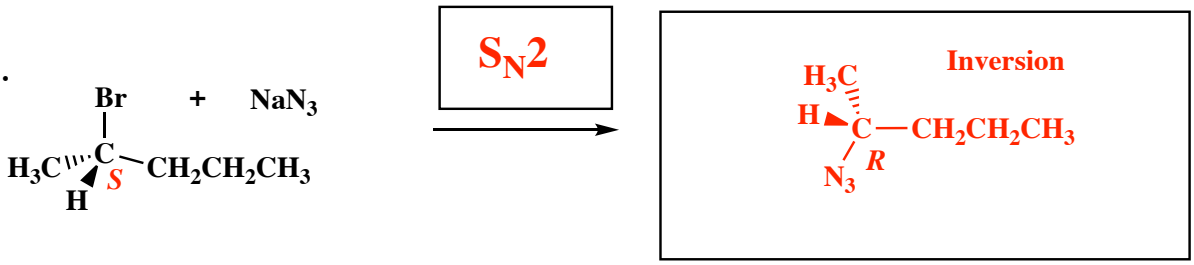
B.



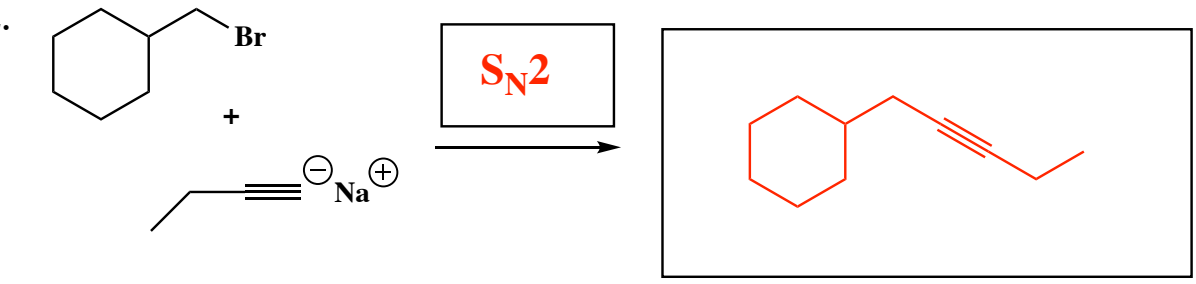
C.



D.

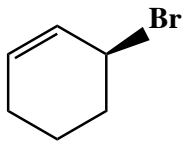


E.



15. (5,7 or 9 pts each) The following reactions all involve chemistry of haloalkanes. **Fill in the box above the arrow with the mechanism that will be followed (S_N2, E2, etc.). Then draw only the predominant product or products** and please remember that **you must draw the correct stereoisomers**. For S_N1/E1 reactions you must draw all significant products (including all stereoisomers).

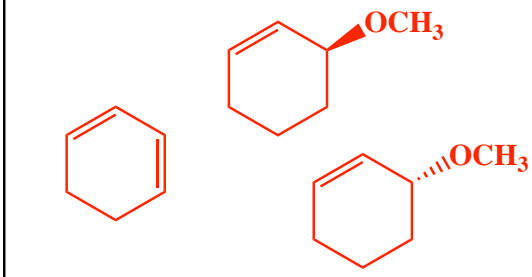
F.



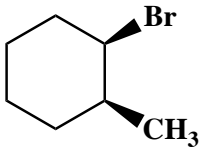
+

CH_3OH

S_N1/E1



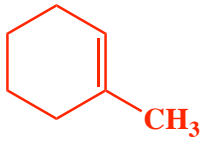
G.



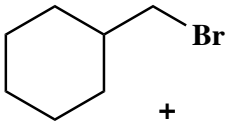
+

$CH_3CH_2O^{\ominus}\ Na^{\oplus}$

E2



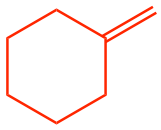
H.



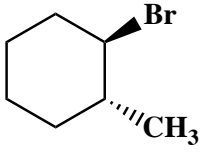
+

$(CH_3)_3CO^{\ominus}\ K^{\oplus}$

E2



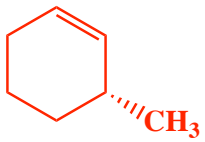
I.



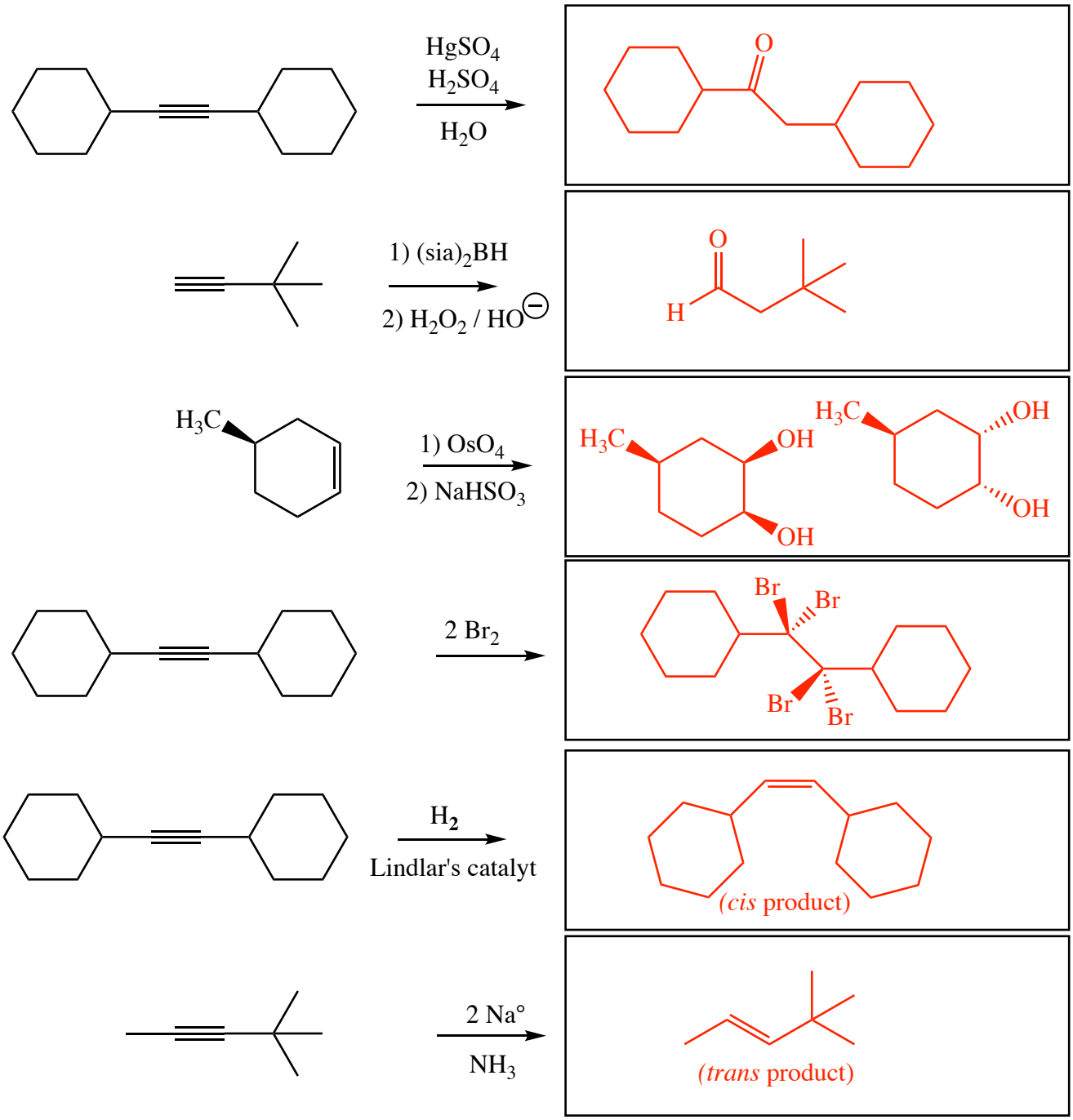
+

$CH_3CH_2O^{\ominus}\ Na^{\oplus}$

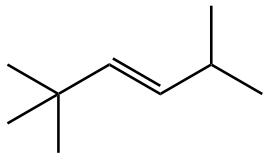
E2



16. (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 a racemic mixture is formed, **you must write "racemic" under both structures EVEN THOUGH YOU DREW BOTH STRUCTURES**.

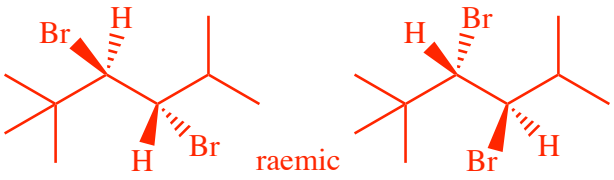


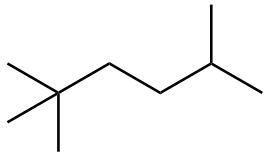
17. (3 or 5 pts each) The following reactions all involve chemistry of alkenes. Fill in the box with the product(s) that are missing from the chemical reaction equations. **Draw only the predominant regioisomer product or products (i.e. Markovnikov or non-Markovnikov products)** and please remember that **you must draw the structures of all the product stereoisomers using wedges and dashes to indicate stereochemistry**. When a racemic mixture is formed, **you must write "racemic" under both structures EVEN THOUGH YOU DREW BOTH STRUCTURES**.



Br_2

(anti addition)

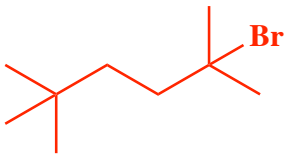


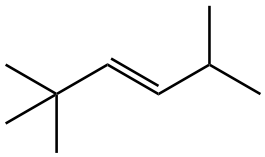


Br_2

hν

(reacts at more substituted C atom)

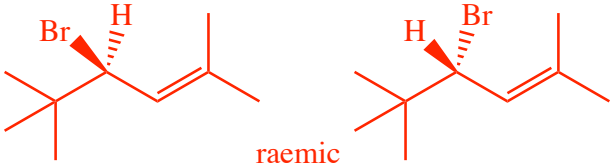


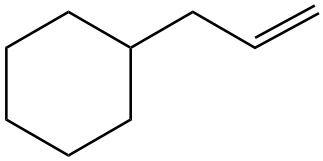


NBS

hν

(allylic halogenation)



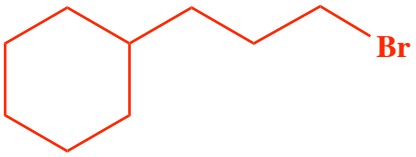


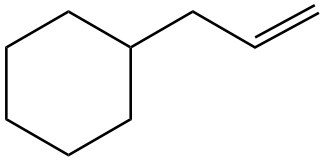
HBr

ROOR

hν

(non-Markovnikov)

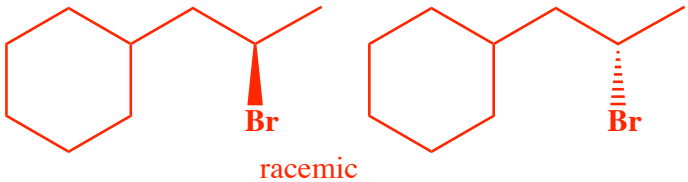




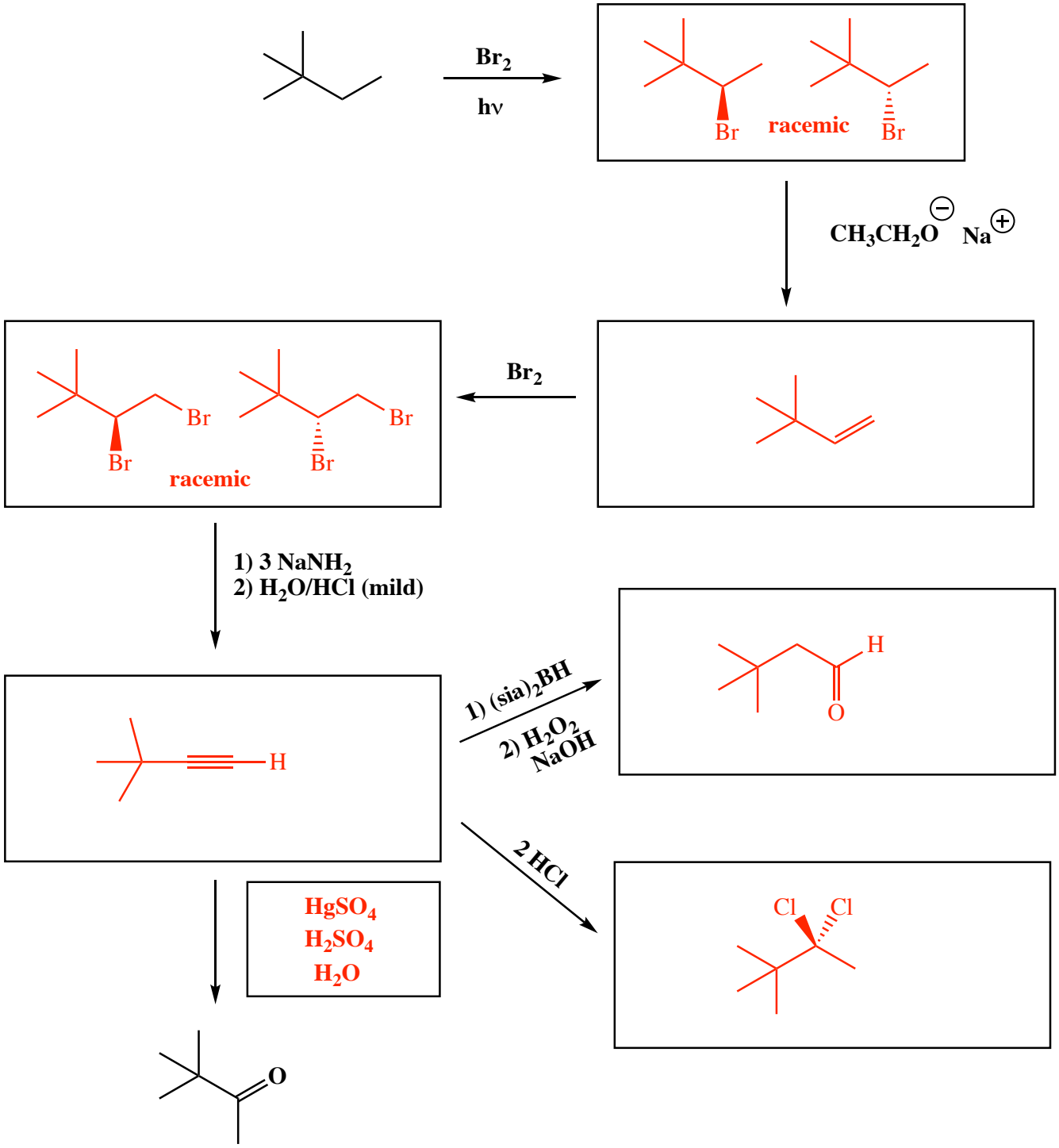
HBr

(assume NO rearrangement)

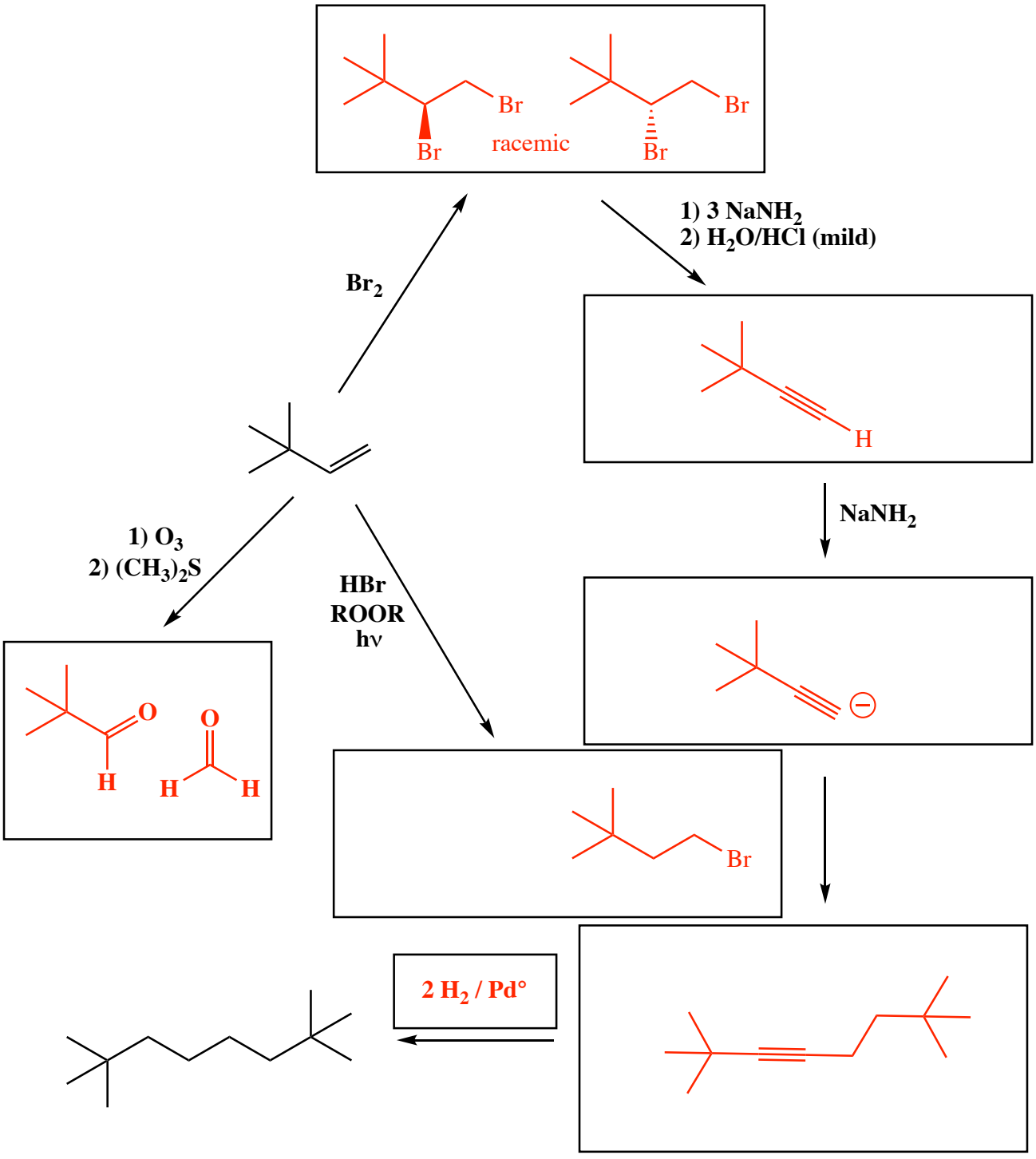
(Markovnikov)



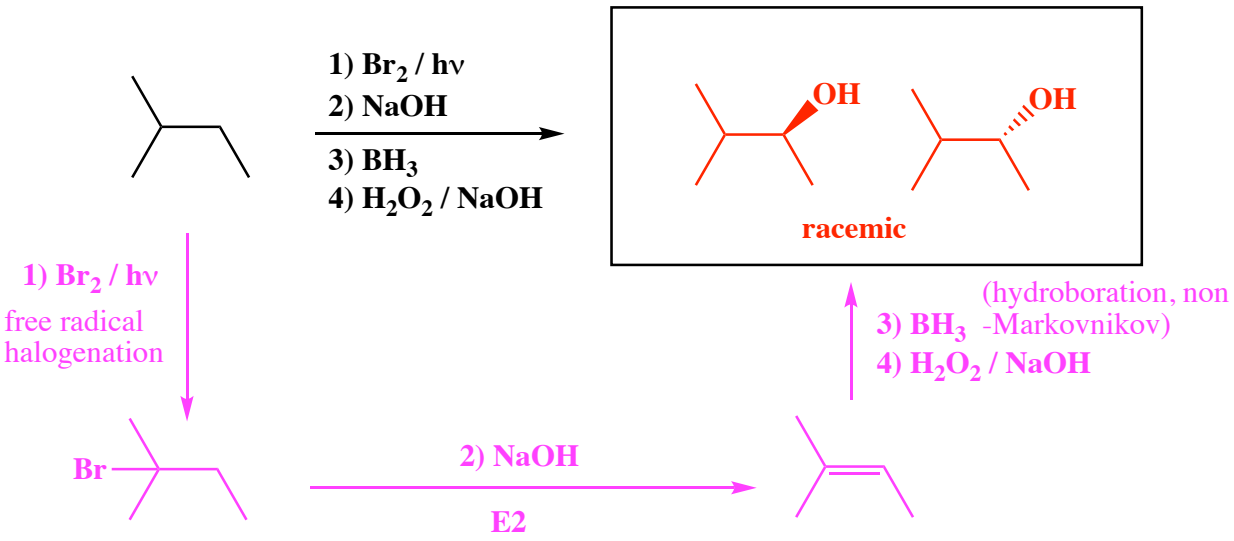
18. (3 or 5 pts each) For the following reactions, fill in the box with the predominant **products** or **reagents** necessary to complete the following syntheses. **You must indicate stereochemistry with wedges and dashes. You must draw all stereoisomers** produced as predominant products and **write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



18. (3, 4 or 5 pts each) For the following reactions, fill in the box with the predominant **products** or **reagents** necessary to complete the following syntheses. **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. (5 pts) For the following sequence of reactions, **draw the final product(s)**. You only need to draw the very last product(s) in the box provided, although feel free to draw any other structures in the empty space provided. We will only grade the structure(s) in the box. As always, if a racemic mixture is created you need to draw both enantiomers using wedges and dashes and write "racemic".



20. (5 pts) Save this until last. Super challenge problem. In the box provided, **draw the starting material** that leads to the product shown. Feel free to draw any other structures in the empty space provided. We will only grade the structure in the box.