

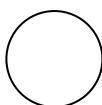
Name: \_\_\_\_\_

Student ID Number: \_\_\_\_\_

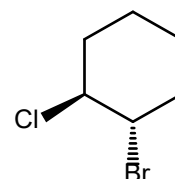
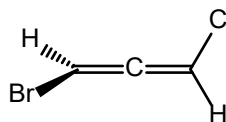
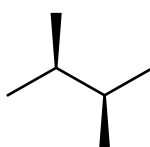
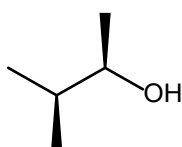
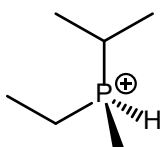
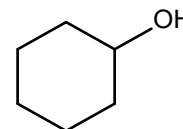
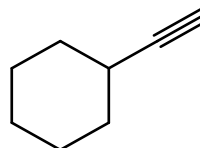
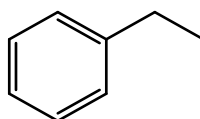
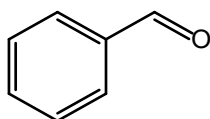
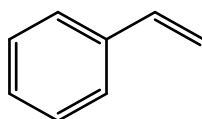
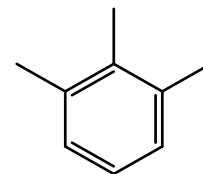
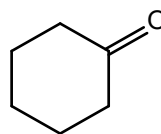
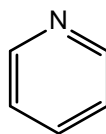
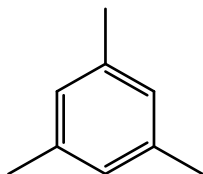
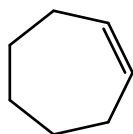
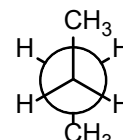
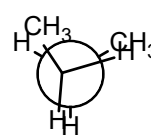
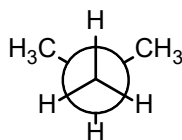
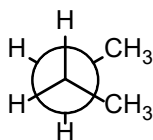
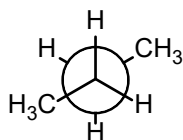
(print legibly) Last

First

**Read all directions very carefully.** Write your answer legibly in the designated spaces. Total number of points is 400. This exam is printed on both sides and should have eight pages, with the last two intentionally left empty.

1. This question has several parts. In each, **circle only one entry**.

5×8 = 40 points

Circle the only achiral compound:Circle the only compound that would show a strong IR absorption around 1700 cm<sup>-1</sup>:Circle the only compound which would show only singlets in an <sup>1</sup>H NMR spectrum:Circle the only conformation that does not represent the molecule of butane:Circle the approximate barrier to the rotation around the C–C bond in ethane:160 kcal mol<sup>-1</sup>3 kcal mol<sup>-1</sup>–30 kcal mol<sup>-1</sup>

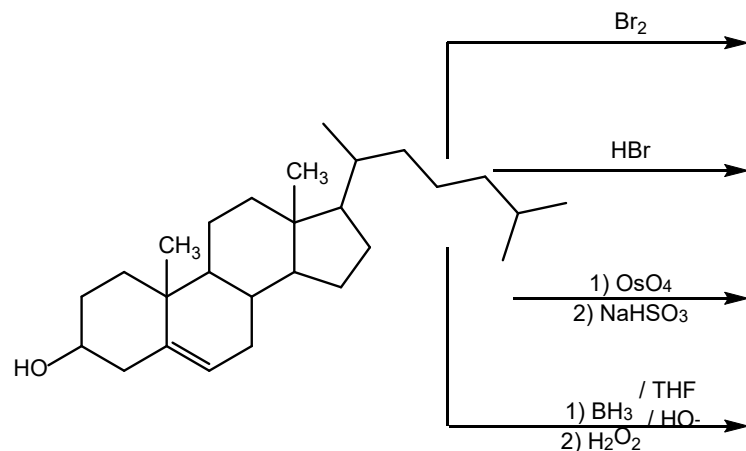
150 pm

10<sup>4</sup> kcal mol<sup>-1</sup>DO NOT WRITE  
IN THIS SPACE**FINAL SCORE**

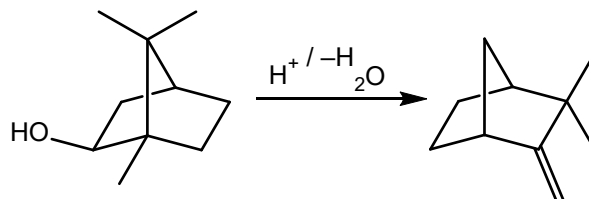
2. Predict the products of the following reactions. Don't worry about the size of the molecule; concentrate on the functional groups.

60 points

Textbook problem 8-46 (McMurry, 10<sup>th</sup> edition)

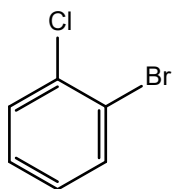


3. Show the arrow-pushing mechanism for the transformation shown below, which involves carbocations intermediate and their rearrangement. HINT: Number the carbon atoms and keep track of them! 50 points

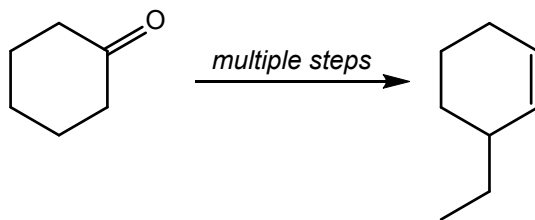


4. Predict the splitting pattern for each kind of hydrogen in the following molecules: (a)  $(\text{CH}_3)_3\text{CH}$ ; (b)  $\text{CH}_3\text{CH}_2\text{CO}_2\text{CH}_3$ , and (c) trans-2-butene. 60 points
- Textbook problem 13-38 (McMurry, 10<sup>th</sup> edition)*

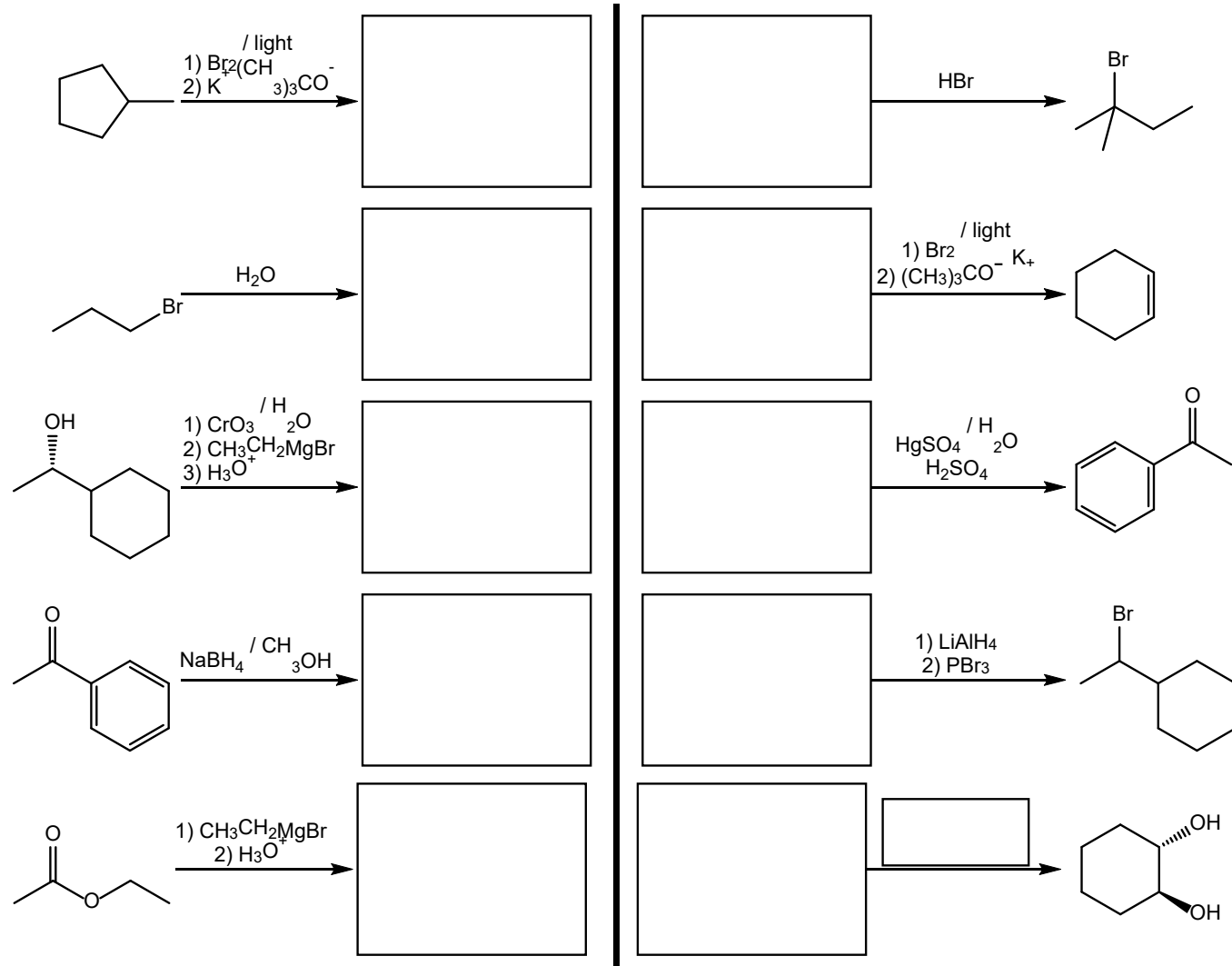
5. Carefully examine the structure of 1-bromo-2-chlorobenzene, shown below. In its mass spectrum, how many molecular ions would you expect, what would be their masses, and their relative ratios? In its  $^1\text{H}$  NMR spectrum, how many peaks would you expect? What would be their multiplicities (singlet, doublet, triplet...) and relative size ratios (integration)? 50 points



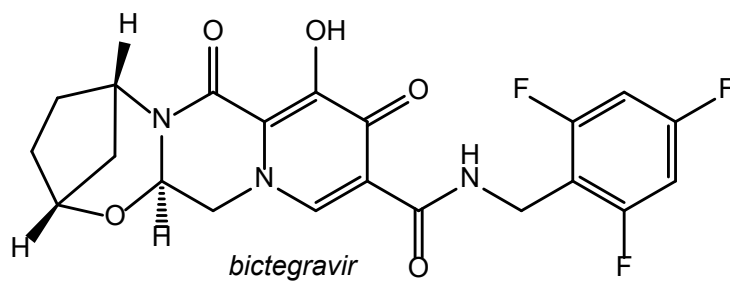
6. How would you efficiently accomplish the following synthetic transformation? Multiple reactions steps will be needed to accomplish this synthesis: draw them all out, but do not include mechanisms. 60 points



7. Write the missing products, reactants, or reagents for the reactions shown below. Make sure to include stereochemistry where pertinent, but do not write mechanisms. 100 points



8. Bictegravir is one of the three compounds used in the modern blockbuster drug mix that suppresses the replication of the HIV virus. It is also a chiral molecule. Circle all its chiral centers and determine the (R)/(S) configuration of any one of them. 20 points



hydrogen 1 <b>H</b> 1.0079																	helium 2 <b>He</b> 4.0026	
lithium 3 <b>Li</b> 6.941	beryllium 4 <b>Be</b> 9.0122																	
sodium 11 <b>Na</b> 22.990	magnesium 12 <b>Mg</b> 24.305																	
potassium 19 <b>K</b> 39.098	calcium 20 <b>Ca</b> 40.078	scandium 21 <b>Sc</b> 44.956	titanium 22 <b>Ti</b> 47.867	vanadium 23 <b>V</b> 50.942	chromium 24 <b>Cr</b> 51.996	manganese 25 <b>Mn</b> 54.938	iron 26 <b>Fe</b> 55.845	cobalt 27 <b>Co</b> 58.933	nickel 28 <b>Ni</b> 58.693	copper 29 <b>Cu</b> 63.546	zinc 30 <b>Zn</b> 65.39	gallium 31 <b>Ga</b> 69.723	germanium 32 <b>Ge</b> 72.61	arsenic 33 <b>As</b> 74.922	selenium 34 <b>Se</b> 78.96	bromine 35 <b>Br</b> 79.904	krypton 36 <b>Kr</b> 83.80	
rubidium 37 <b>Rb</b> 85.468	strontium 38 <b>Sr</b> 87.62	yttrium 39 <b>Y</b> 88.906	zirconium 40 <b>Zr</b> 91.224	niobium 41 <b>Nb</b> 92.906	molybdenum 42 <b>Mo</b> 95.94	technetium 43 <b>Tc</b> [98]	ruthenium 44 <b>Ru</b> 101.07	rhodium 45 <b>Rh</b> 102.91	palladium 46 <b>Pd</b> 106.42	silver 47 <b>Ag</b> 107.87	cadmium 48 <b>Cd</b> 112.41	indium 49 <b>In</b> 114.82	tin 50 <b>Sn</b> 118.71	antimony 51 <b>Sb</b> 121.76	tellurium 52 <b>Te</b> 127.60	iodine 53 <b>I</b> 126.90	xenon 54 <b>Xe</b> 131.29	
caesium 55 <b>Cs</b> 132.91	barium 56 <b>Ba</b> 137.33	57-70 ★	lutetium 71 <b>Lu</b> 174.97	hafnium 72 <b>Hf</b> 178.49	tantalum 73 <b>Ta</b> 180.95	tungsten 74 <b>W</b> 183.84	rhenium 75 <b>Re</b> 186.21	osmium 76 <b>Os</b> 190.23	iridium 77 <b>Ir</b> 192.22	platinum 78 <b>Pt</b> 195.08	gold 79 <b>Au</b> 196.97	mercury 80 <b>Hg</b> 200.59	thallium 81 <b>Tl</b> 204.38	lead 82 <b>Pb</b> 207.2	bismuth 83 <b>Bi</b> 208.98	polonium 84 <b>Po</b> [209]	astatine 85 <b>At</b> [210]	radon 86 <b>Rn</b> [222]
francium 87 <b>Fr</b> [223]	radium 88 <b>Ra</b> [226]	89-102 ★ ★	lawrencium 103 <b>Lr</b> [262]	rutherfordium 104 <b>Rf</b> [261]	dubnium 105 <b>Db</b> [262]	seaborgium 106 <b>Sg</b> [263]	bohrium 107 <b>Bh</b> [264]	hassium 108 <b>Hs</b> [265]	meitnerium 109 <b>Mt</b> [268]	ununilium 110 <b>Uun</b> [271]	unununium 111 <b>Uuu</b> [272]	ununbium 112 <b>Uub</b> [273]	ununquadium 114 <b>Uuq</b> [289]					

\* Lanthanide series

lanthanum 57 <b>La</b> 138.91	cerium 58 <b>Ce</b> 140.12	praseodymium 59 <b>Pr</b> 140.91	neodymium 60 <b>Nd</b> 144.24	promethium 61 <b>Pm</b> [145]	samarium 62 <b>Sm</b> 150.36	europium 63 <b>Eu</b> 151.96	gadolinium 64 <b>Gd</b> 157.25	terbium 65 <b>Tb</b> 158.93	dysprosium 66 <b>Dy</b> 162.50	holmium 67 <b>Ho</b> 164.93	erbium 68 <b>Er</b> 167.26	thulium 69 <b>Tm</b> 168.93	ytterbium 70 <b>Yb</b> 173.04
actinium 89 <b>Ac</b> [227]	thorium 90 <b>Th</b> 232.04	protactinium 91 <b>Pa</b> 231.04	uranium 92 <b>U</b> 238.03	neptunium 93 <b>Np</b> [237]	plutonium 94 <b>Pu</b> [244]	americium 95 <b>Am</b> [243]	curium 96 <b>Cm</b> [247]	berkelium 97 <b>Bk</b> [247]	californium 98 <b>Cf</b> [251]	einsteinium 99 <b>Es</b> [252]	fermium 100 <b>Fm</b> [257]	mendelevium 101 <b>Md</b> [258]	nobelium 102 <b>No</b> [259]

\*\* Actinide series

## Characteristic Infrared (IR) Spectroscopy Vibrations

Functional Group	Absorption (cm <sup>-1</sup> )	Intensity
Alkane	C-H	2850-2960
Alkene	=C-H	3020-3100
	C=C	1640-1680
Alkyne	≡C-H	3300
	C≡C	2100-2260
Alcohol	O-H	3400-3650
	C-O	1050-1150
Amine	N-H	3300-3500
	C-N	1030-1230
Carbonyls	C=O	1670-1780
Aldehyde		1730
Ketone		1715
Ester		1735
Amide		1690
Carboxylic acid		1710
Carboxylic acid O-H		2500-3100
Nitrile	C≡N	2210-2260



