

NAME (Print): _____

Chemistry 320M/328M
Dr. Brent Iverson
3rd Midterm
November 21, 2024

EID _____

SIGNATURE: _____

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

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Please Note: Please take your time. We are giving you three hours to take this exam. The idea is to give you enough time to show us what you know, not how fast you can draw structures. Please take all the time you need to draw the best possible structures that you can! Do not be surprised if you are comfortable leaving the exam before 9 PM.

FINALLY, DUE TO SOME UNFORTUNATE RECENT INCIDENTS 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!!!

Student Honor Code for the University of Texas at Austin

"I pledge, as a member of The University of Texas at Austin community, to do my work honestly, respectfully, and through the intentional pursuit of learning and scholarship."

Elaboration

1. I pledge to be honest about what I create and to acknowledge what I use that belongs to others.
2. I pledge to value the process of learning in addition to the outcome, while celebrating and learning from mistakes.
3. This code encompasses all of the academic and scholarly endeavors of the university community.

(Your signature)

PERIODIC TABLE OF THE ELEMENTS

Elementary Subatomic Particles										Ionic Character of a Single Chemical Bond													
Electron		Proton		Neutron		Positron		Antineutrino		Difference in Electronegativity		% Ionic Character		% Ionic Character		% Ionic Character		% Ionic Character					
Symbol	Mass	Charge	Symbol	Mass	Charge	Symbol	Mass	Charge	Symbol	Mass	Charge	Symbol	Mass	Charge	Symbol	Mass	Charge	Symbol	Mass	Charge			
Electron	9.10938261 × 10 ⁻³¹	-1.602176634 × 10 ⁻¹⁹	Proton	1.6726219 × 10 ⁻²⁷	+1.602176634 × 10 ⁻¹⁹	Neutron	1.6749273 × 10 ⁻²⁷	0	0	Positron	9.10938261 × 10 ⁻³¹	+1.602176634 × 10 ⁻¹⁹	Antineutrino	9.10938261 × 10 ⁻³¹	0	0	0	0	0	0			
Hydrogen mass ratio	1.00782503223		Helium mass ratio	4.00260325415		Lithium mass ratio	7.01600343637		Beryllium mass ratio	9.01218225268		Boron mass ratio	10.0128468881		Carbon mass ratio	12.0107259546		Nitrogen mass ratio	14.0030740049		Oxygen mass ratio	15.9949146196	
Atomic number	Z		Atomic number	Z		Atomic number	Z		Atomic number	Z		Atomic number	Z		Atomic number	Z		Atomic number	Z		Atomic number	Z	

Ionic Character of a Single Chemical Bond																	
Difference in Electronegativity		% Ionic Character		% Ionic Character		% Ionic Character		% Ionic Character		% Ionic Character		% Ionic Character		% Ionic Character		% Ionic Character	
ΔEN	% Ionic	ΔEN	% Ionic	ΔEN	% Ionic	ΔEN	% Ionic	ΔEN	% Ionic	ΔEN	% Ionic	ΔEN	% Ionic	ΔEN	% Ionic	ΔEN	% Ionic
0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0
1.0	1.6	1.6	2.2	2.2	2.8	2.8	3.4	3.4	4.0	4.0	4.6	4.6	5.2	5.2	5.8	5.8	6.4
7.0	7.6	7.6	8.2	8.2	8.8	8.8	9.4	9.4	10.0	10.0	10.6	10.6	11.2	11.2	11.8	11.8	12.4

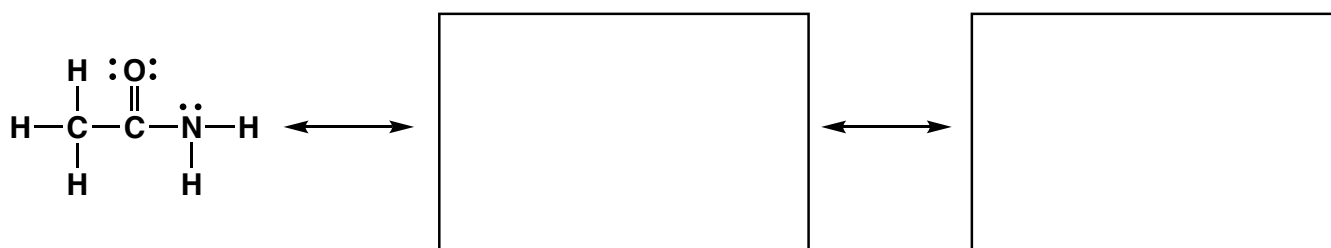
Periodic Table of the Elements																																			
1 IA		2 IIA		3-10										11 IB		12 IIB		13 IIIA		14 IVA		15 VA		16 VIA		17 VIIA		18 VIII							
Group	Element	Group	Element	Group	Element	Group	Element	Group	Element	Group	Element	Group	Element	Group	Element	Group	Element	Group	Element	Group	Element	Group	Element	Group	Element	Group	Element	Group	Element						
1	H	2	He	3	Li	4	Be	5	B	6	C	7	N	8	O	9	F	10	Ne	11	Na	12	Mg	13	Al	14	Si	15	P	16	S	17	Cl	18	Ar
19	K	20	Ca	21	Sc	22	Ti	23	V	24	Cr	25	Mn	26	Fe	27	Co	28	Ni	29	Cu	30	Zn	31	Ga	32	Ge	33	As	34	Se	35	Br	36	Kr
37	Rb	38	Sr	39	Y	40	Zr	41	Nb	42	Mo	43	Tc	44	Ru	45	Rh	46	Pd	47	Ag	48	Cd	49	In	50	Sn	51	Sb	52	Te	53	I	54	Xe
55	Cs	56	Ba	57	La	72	Hf	73	Ta	74	W	75	Re	76	Os	77	Ir	78	Pt	79	Au	80	Hg	81	Tl	82	Pb	83	Bi	84	Po	85	At	86	Rn
87	Fr	88	Ra	89	Ac	104	Unq	105	Unp	106	Unh	107	Uns	108	Uno	109	Uue	110	Uun																

Detailed Periodic Table																			
Group	Element	Group	Element	Group	Element	Group	Element	Group	Element	Group	Element	Group	Element	Group	Element	Group	Element	Group	Element
1	H	2	He	3	Li	4	Be	5	B	6	C	7	N	8	O	9	F	10	Ne
11	Na	12	Mg	13	Al	14	Si	15	P	16	S	17	Cl	18	Ar	19	K	20	Ca
21	Sc	22	Ti	23	V	24	Cr	25	Mn	26	Fe	27	Co	28	Ni	29	Cu	30	Zn
31	Ga	32	Ge	33	As	34	Se	35	Br	36	Kr	37	Rb	38	Sr	39	Y	40	Zr
41	Nb	42	Mo	43	Tc	44	Ru	45	Rh	46	Pd	47	Ag	48	Cd	49	In	50	Sn
51	Sb	52	Te	53	I	54	Xe	55	Cs	56	Ba	57	La	72	Hf	73	Ta	74	W
61	Pr	62	Nd	63	Pm	64	Sm	65	Eu	66	Gd	67	Tb	68	Dy	69	Ho	70	Er
71	Lu	72	Hf	73	Ta	74	W	75	Re	76	Os	77	Ir	78	Pt	79	Au	80	Hg
81	Tl	82	Pb	83	Bi	84	Po	85	At	86	Rn	87	Fr	88	Ra	89	Ac	104	Unq
91	Th	92	Pa	93	U	94	Np	95	Pu	96	Am	97	Cm	98	Bk	99	Cf	100	Fm
101	Md	102	No	103	Lr														

Compound		pK _a
Hydrochloric acid	H-Cl	-7
Protonated alcohol	$\text{RCH}_2\text{OH}_2^{\oplus}$	-2
Hydronium ion	$\text{H}_3\text{O}^{\oplus}$	-1.7
Carboxylic acids	$\text{R}-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$	3-5
Thiols	RCH_2SH	8-9
Ammonium ion	$\text{H}_4\text{N}^{\oplus}$	9.2
β-Dicarbonyls	$\text{RC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{CR}'$	10
Primary ammonium	$\text{H}_3\text{N}^{\oplus}\text{CH}_2\text{CH}_3$	10.5
β-Ketoesters	$\text{RC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OR}'$	11
β-Diesters	$\text{ROC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OR}'$	13
Water	HOH	15.7
Alcohols	RCH_2OH	15-19
Acid chlorides	$\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{Cl}$	16
Aldehydes	$\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$	18-20
Ketones	$\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{CR}'$	18-20
Esters	$\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OR}'$	23-25
Terminal alkynes	$\text{RC}\equiv\text{C}-\text{H}$	25
LDA	$\text{H}-\text{N}(\text{i-C}_3\text{H}_7)_2$	40
Terminal alkenes	$\text{R}_2\text{C}=\underset{\text{H}}{\text{C}}-\text{H}$	44
Alkanes	$\text{CH}_3\text{CH}_2-\text{H}$	51

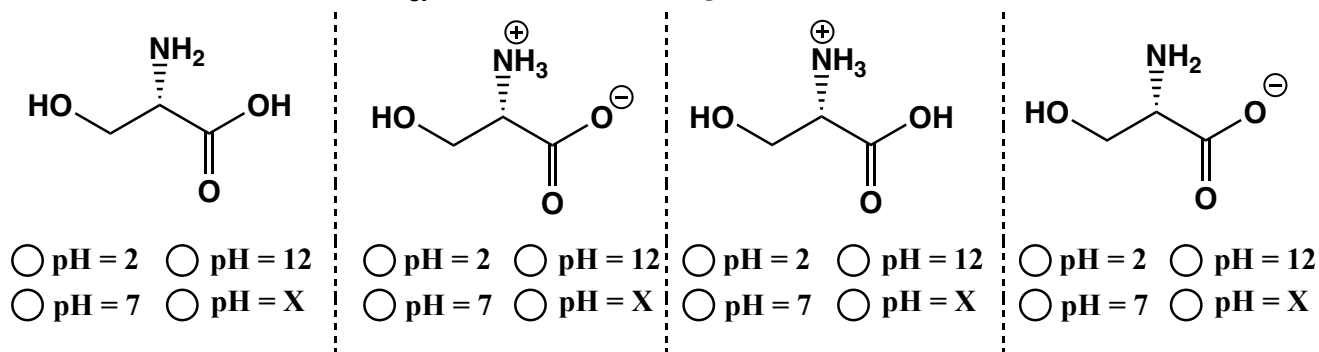
1. (5 pts) What is the most important question in organic chemistry?

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, use arrows to indicate the movement of electrons to give the structures you drew.

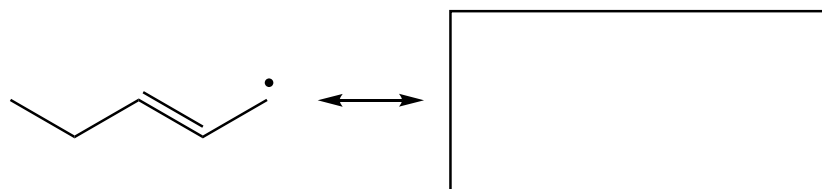


3. (8 pts.) Fill in the circle next to the pH value that corresponds to the pH at which the structure drawn would be present. If the structure drawn cannot exist at any pH, fill in the circle next to the "pH = X"

The pK_a of a carboxylic acid (RCO_2H) is generally in the 4-5 range. The pK_a of ammonium ions (RNH_3^+) is in the 9-10 range.



4. (10 pts.) Draw the other important contributing structure for this allyl radical. Draw arrows on the structure given that leads to the contributing structure you drew. Remember to include all formal charges and unpaired electrons.



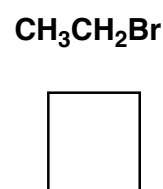
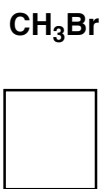
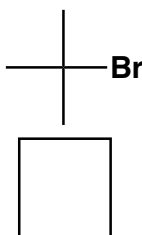
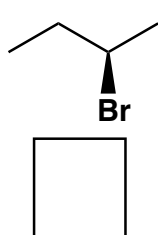
Fill in the circle to indicate how many pi electrons are in the delocalized pi system ("pi-way") indicated by the two contributing structures

0
 2
 3
 4

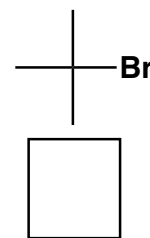
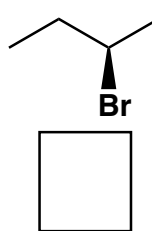
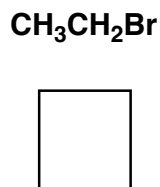
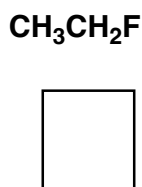
5. (11 pts) Consider the following statements that refer to **S_N1**, **S_N2**, **E1**, **E2**, or a **radical chain reaction** mechanisms. Fill in the circles to indicate to which mechanism(s) each statement applies. You may need to fill in more than one circle for some of these.

A. A reaction mechanism that involves a radical intermediate.	<input type="radio"/> S _N 2 <input type="radio"/> S _N 1	<input type="radio"/> E2 <input type="radio"/> E1	<input type="radio"/> Radical chain reaction
B. A reaction that involves initiation, propagation and termination steps.	<input type="radio"/> S _N 2 <input type="radio"/> S _N 1	<input type="radio"/> E2 <input type="radio"/> E1	<input type="radio"/> Radical chain reaction
C. A reaction that will occur when Br ₂ and light (hν) are used with an alkane.	<input type="radio"/> S _N 2 <input type="radio"/> S _N 1	<input type="radio"/> E2 <input type="radio"/> E1	<input type="radio"/> Radical chain reaction
D. A reaction mechanism that involves only a transition state, no intermediate.	<input type="radio"/> S _N 2 <input type="radio"/> S _N 1	<input type="radio"/> E2 <input type="radio"/> E1	<input type="radio"/> Radical chain reaction
E. A reaction that causes only InVERSiON of stereochemistry at the site of reaction.	<input type="radio"/> S _N 2 <input type="radio"/> S _N 1	<input type="radio"/> E2 <input type="radio"/> E1	<input type="radio"/> Radical chain reaction
F. The mechanism that occurs when a secondary alcohol reacts with catalytic H ₂ SO ₄ to give an alkene product.	<input type="radio"/> S _N 2 <input type="radio"/> S _N 1	<input type="radio"/> E2 <input type="radio"/> E1	<input type="radio"/> Radical chain reaction
G. A reaction mechanism that involves a carbocation intermediate.	<input type="radio"/> S _N 2 <input type="radio"/> S _N 1	<input type="radio"/> E2 <input type="radio"/> E1	<input type="radio"/> Radical chain reaction
H. A reaction mechanism that involves “scrambling” of stereochemistry at the site of reaction.	<input type="radio"/> S _N 2 <input type="radio"/> S _N 1	<input type="radio"/> E2 <input type="radio"/> E1	<input type="radio"/> Radical chain reaction
I. A reaction mechanism that happens when NBS and light or heat are used with an alkene.	<input type="radio"/> S _N 2 <input type="radio"/> S _N 1	<input type="radio"/> E2 <input type="radio"/> E1	<input type="radio"/> Radical chain reaction

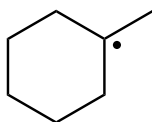
6. (4 pts) Rank the following four molecules with respect to their ability to react according to an S_N2 mechanism. **Put a 1 under the most reactive and a 4 under the least reactive molecule.**



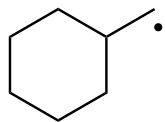
7. (4 pts) Rank the following four molecules with respect to their ability to react according to an S_N1/E1 mechanism. **Put a 1 under the most reactive and a 4 under the least reactive molecule.**



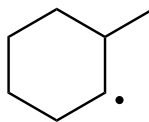
8. (4 pts each) For the following lists of structures, fill in the circles as appropriate to indicate which molecules of the four listed correspond to the parameter listed. **You will only fill in two circles per four molecules listed.**

Radical Stability

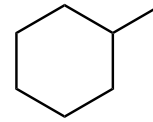
- Most Stable
 Least Stable



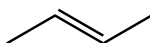
- Most Stable
 Least Stable



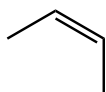
- Most Stable
 Least Stable



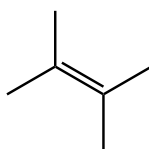
- Most Stable
 Least Stable

Alkene Stability

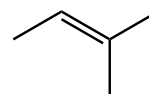
- Most Stable
 Least Stable



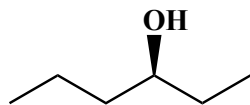
- Most Stable
 Least Stable



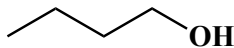
- Most Stable
 Least Stable



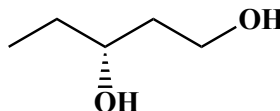
- Most Stable
 Least Stable

Solubility in water

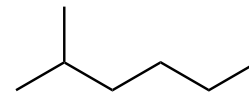
- Most Soluble
 Least Soluble



- Most Soluble
 Least Soluble

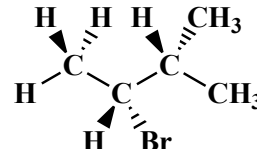
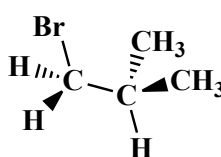
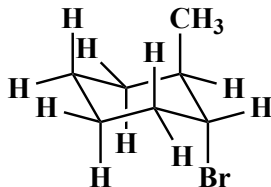
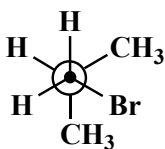


- Most Soluble
 Least Soluble

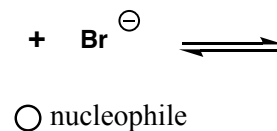
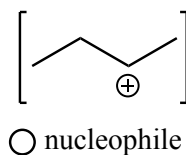
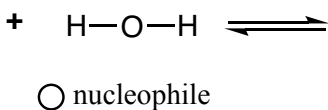
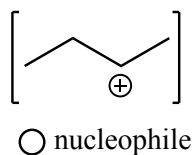
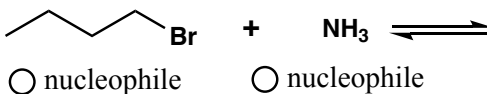
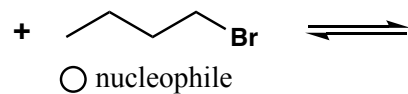
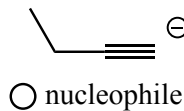


- Most Soluble
 Least Soluble

9. (3 pts each) In each case, circle the one H atom that will react during an E2 reaction in strong base to give the predominant product.



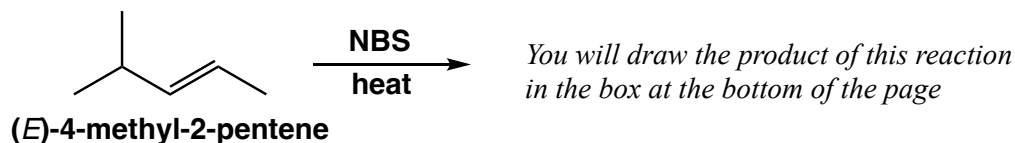
10. (2 pts each) For the following four pairs of reagents you have seen in various bond-making steps in mechanisms, **fill in the circle to indicate which structure is acting as a nucleophile.**



11. (7 pts) In the space provided, draw Lewis structures for two ethanol molecules ($\text{CH}_3\text{CH}_2\text{OH}$) with one hydrogen bond between them indicated by a dashed line. Make sure to include all appropriate lone pairs of electrons in your answer.



12. (8 pts) Consider what happens when (*E*)-4-methyl-2-pentene is reacted with NBS and heat.



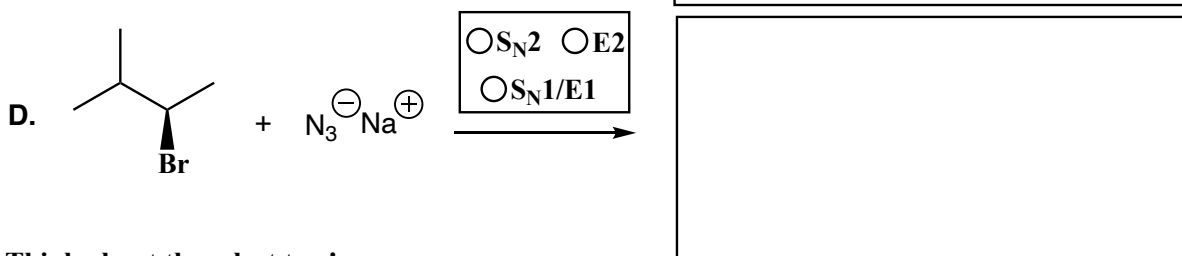
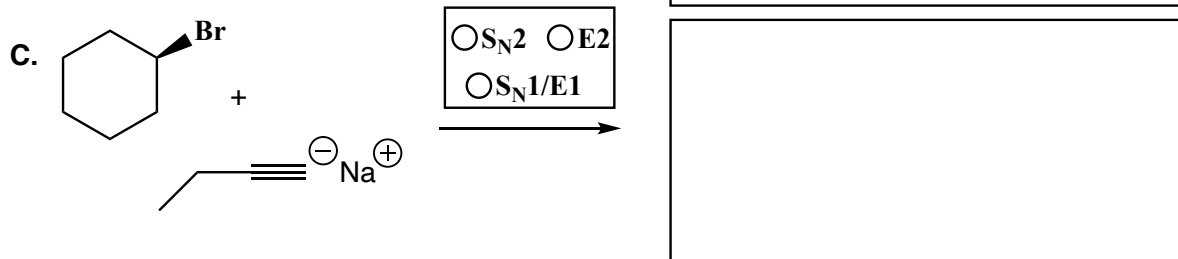
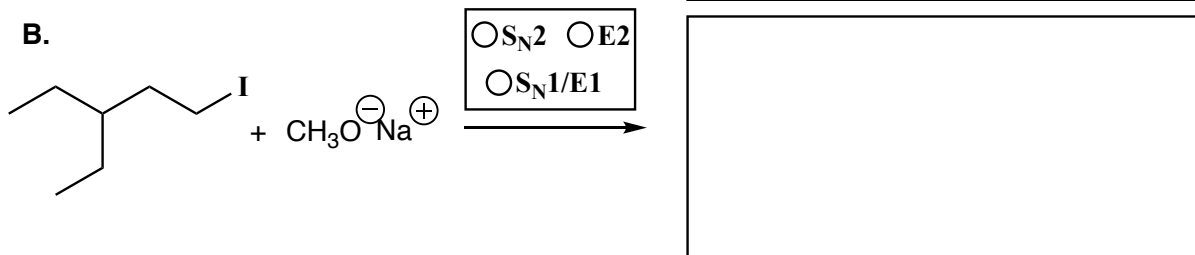
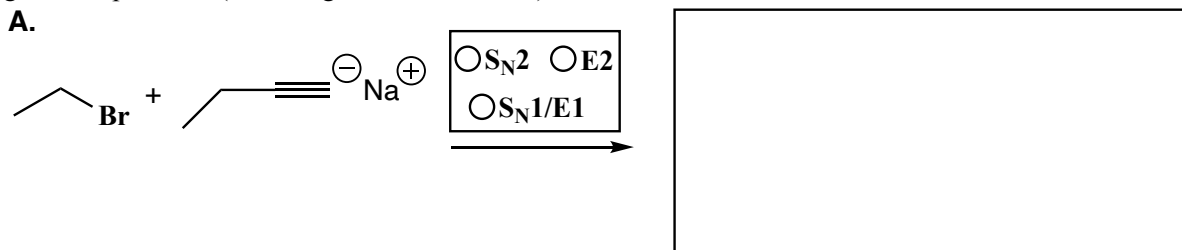
Fill in the circles to indicate which allyl radical contributing structures are relevant and therefore must be considered when predicting the predominant product of the reaction

- | | | | |
|--|--|--|--|
| | | | |
| <input type="radio"/> This contributing structure should be considered | <input type="radio"/> This contributing structure should be considered | <input type="radio"/> This contributing structure should be considered | <input type="radio"/> This contributing structure should be considered |
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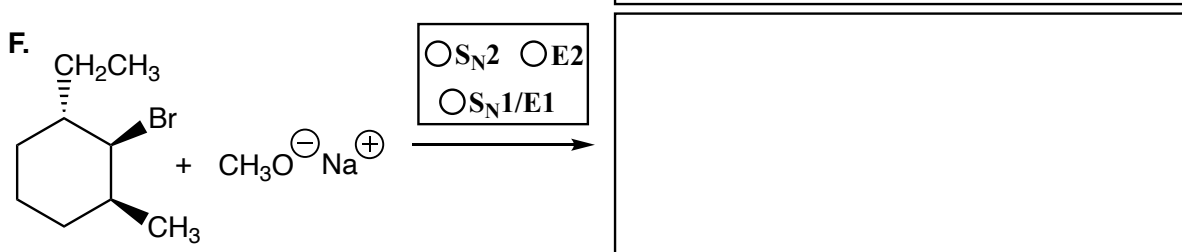
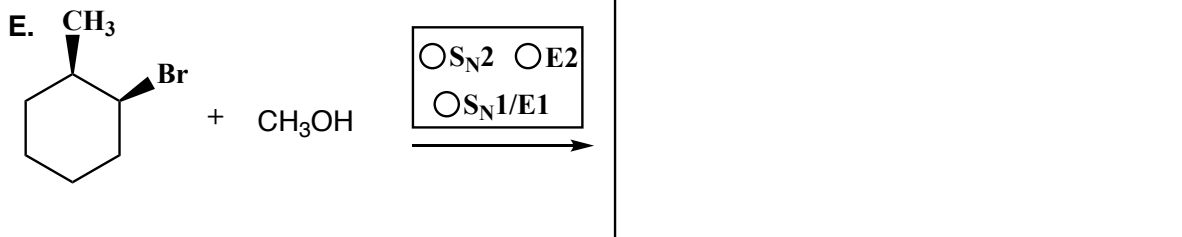
(6 pts) Given your analysis of the above contributing structures, in the box provided, draw the product of the reaction of (*E*)-4-methyl-2-pentene with NBS and heat. Use wedges and dashes to indicate stereochemistry, and draw all relevant stereoisomers, indicating the product is racemic if appropriate.



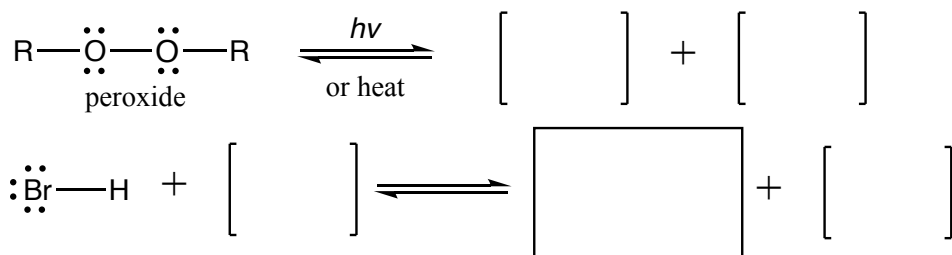
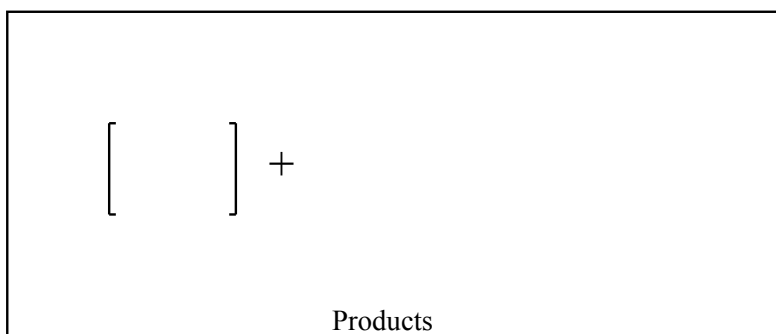
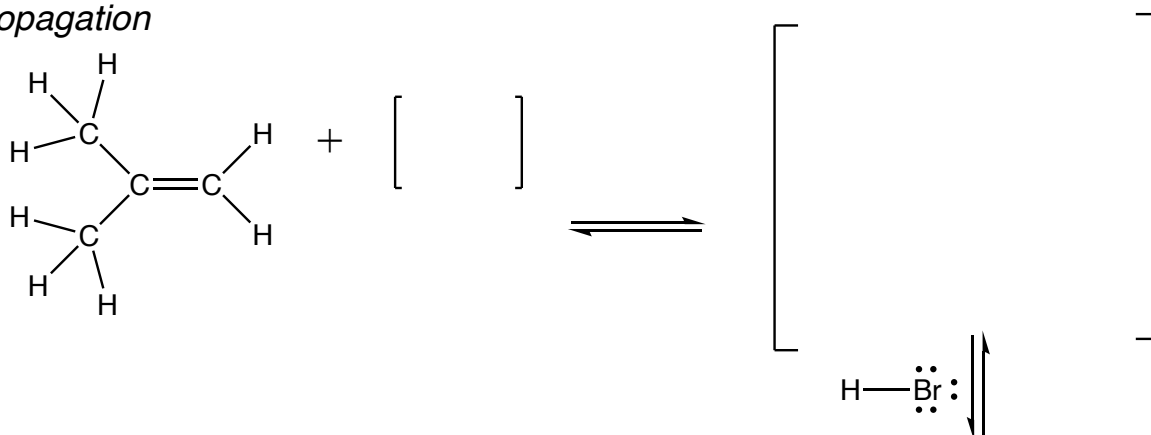
14. (5 or 6 pts each) The following reactions all involve the chemistry of haloalkanes. **Fill in the circle above the arrow to indicate the mechanism that will be followed (S_N2 , $E2$, etc.). Then draw only the predominant product or products and please remember that you must draw the correct stereoisomers using wedges and dashes, writing "racemic" if appropriate. For $S_N1/E1$ reactions you must draw all significant products (including all stereoisomers).**



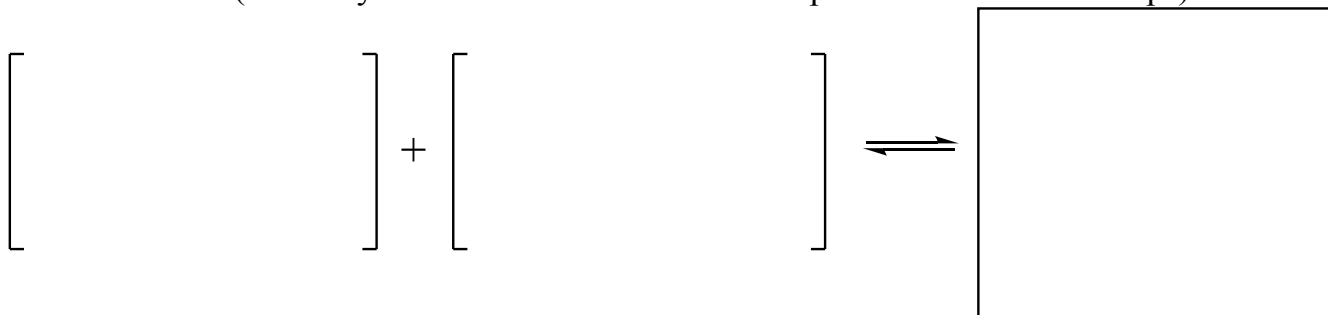
Think about these last two!



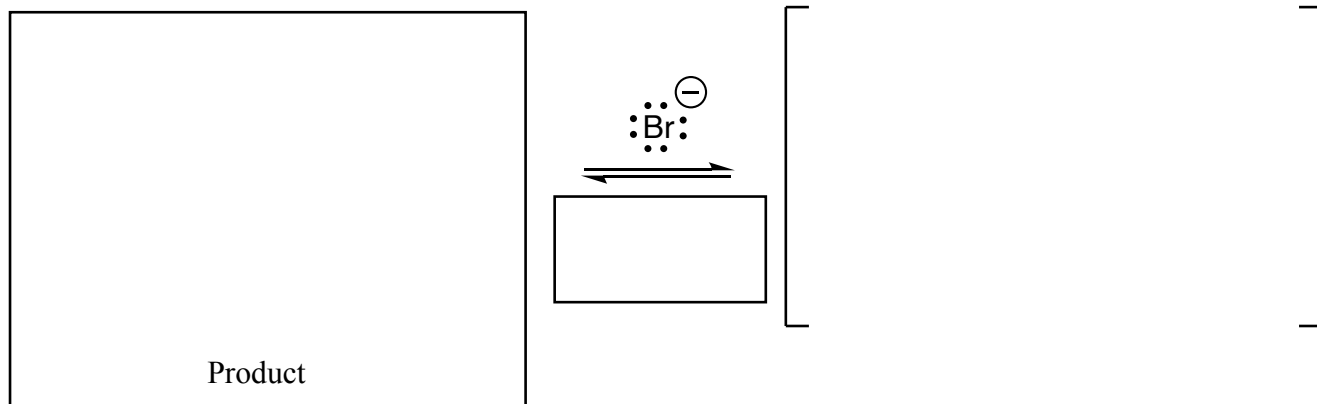
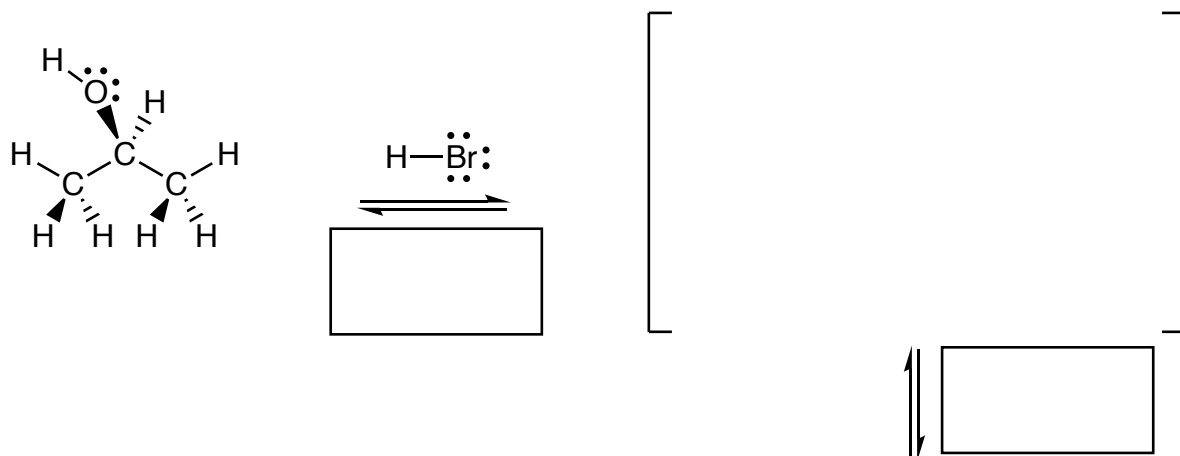
15. (34 pts total) Complete the following mechanism for the free radical addition of HBr to an alkene. Use appropriate arrows to show movement of electron density, and show all non-bonding electrons as dots and show any formal charges. **If any of the species are really a racemic mixtures of enantiomers, you only need to draw one stereoisomer using wedges and dashes, indicating the chiral center with an asterisk (*) and write "racemic".** Note that for the termination step, you only need to draw one of the three possible examples of termination.

Initiation*Propagation*

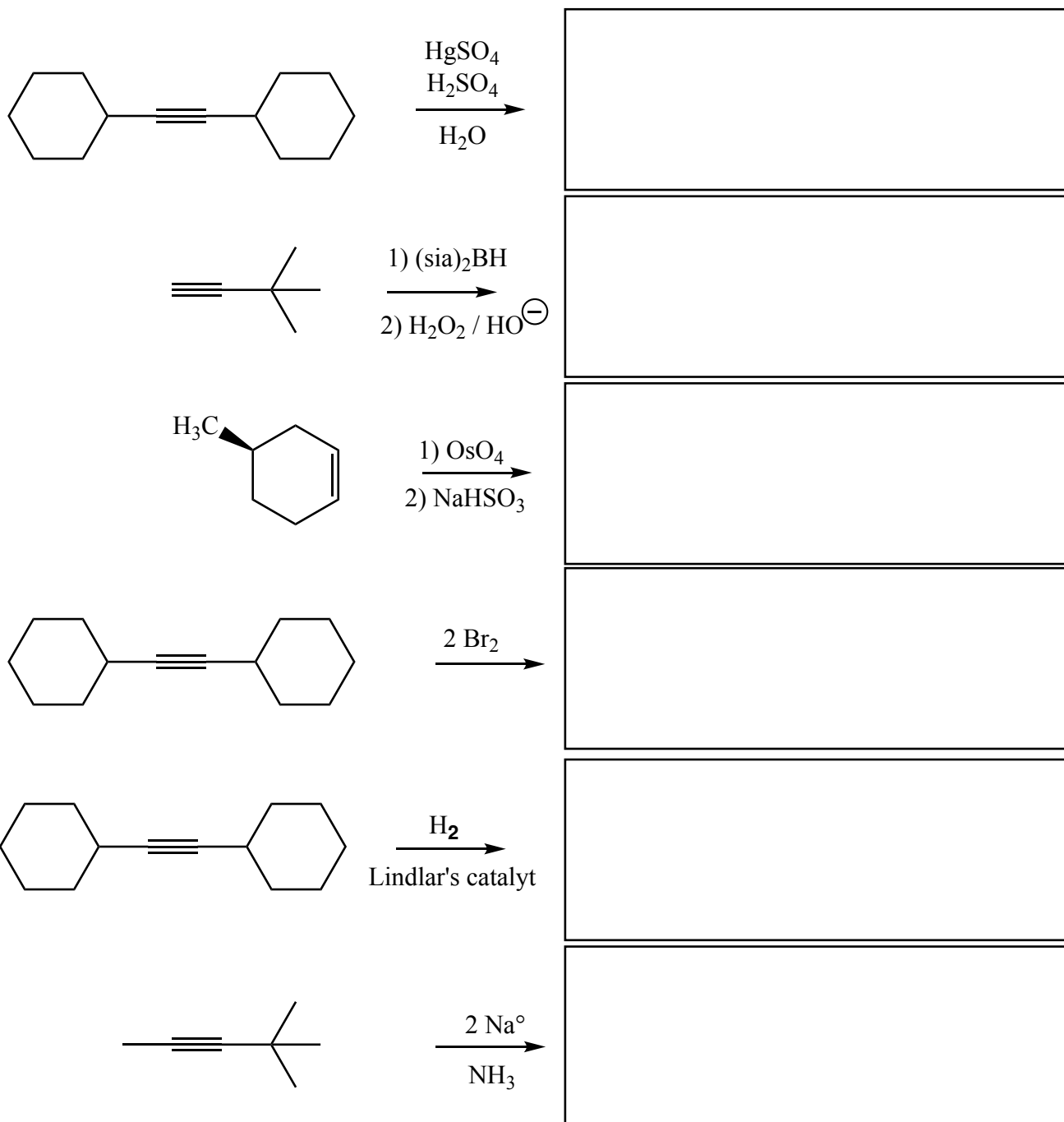
Termination (You only need to show one of the three possible termination steps)



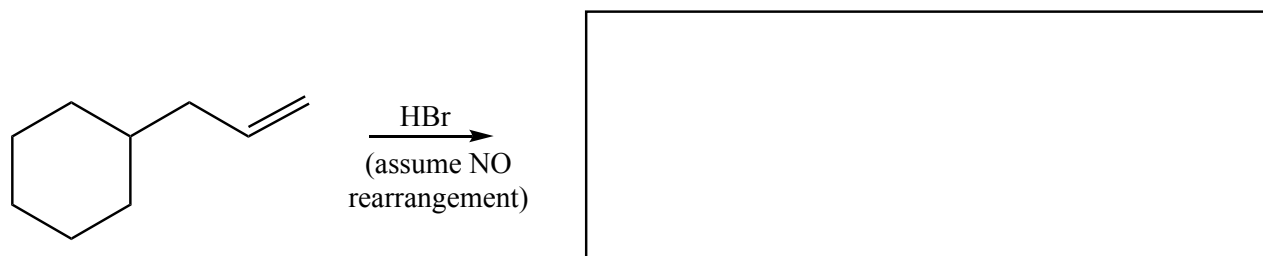
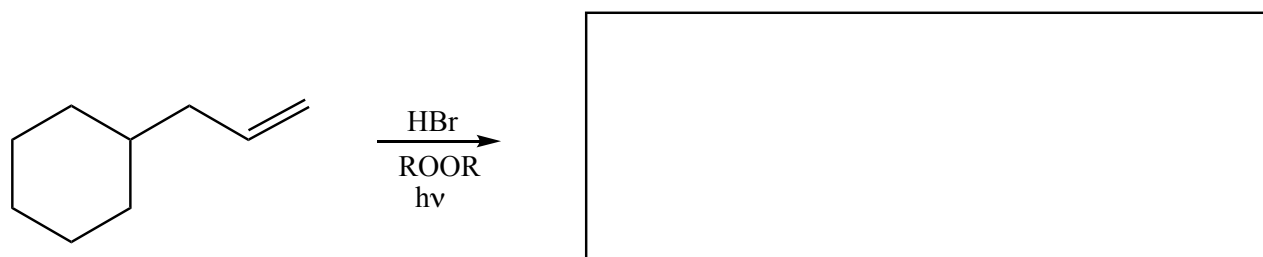
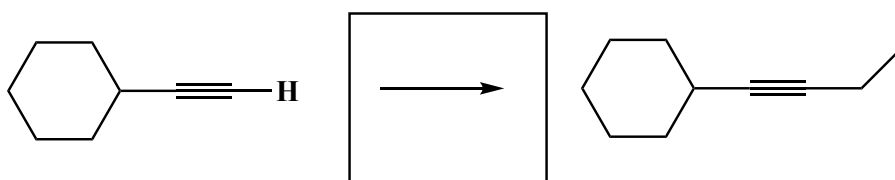
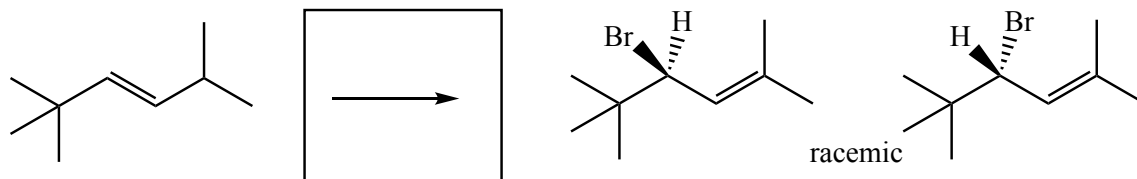
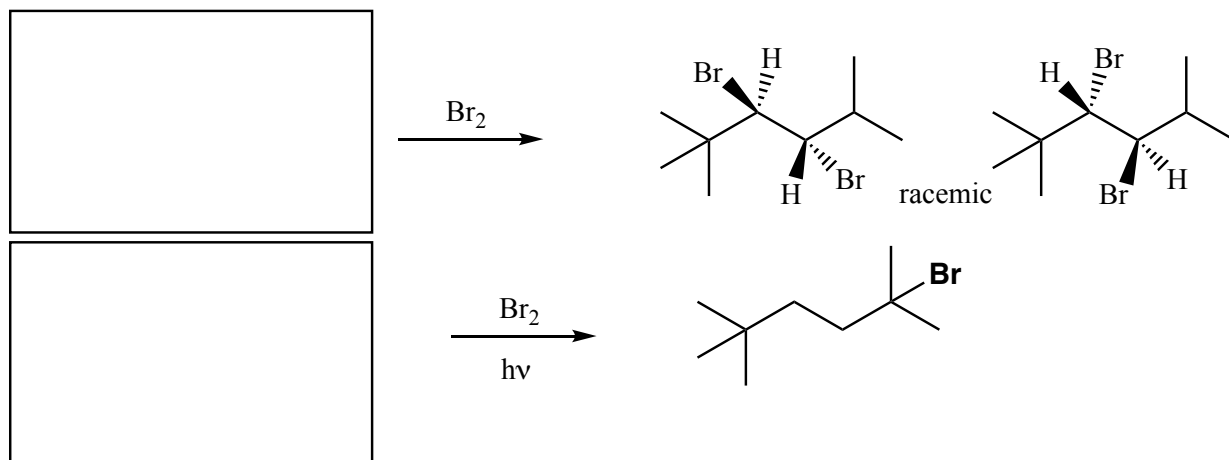
16. (18 pts) Complete the mechanism for the following reaction of an alcohol with H-Br. Be sure to show arrows to indicate movement of all electrons, write all lone pairs, all formal charges, and all the products for each step. Remember, I said all the products for each step. **If any of the species are really a racemic mixtures of enantiomers, you only need to draw one stereoisomer using wedges and dashes, indicating the chiral center with an asterisk (*) and write "racemic".** In the three boxes provided, write which of the 4 most common mechanistic elements describes each step (make a bond, break a bond, etc.).



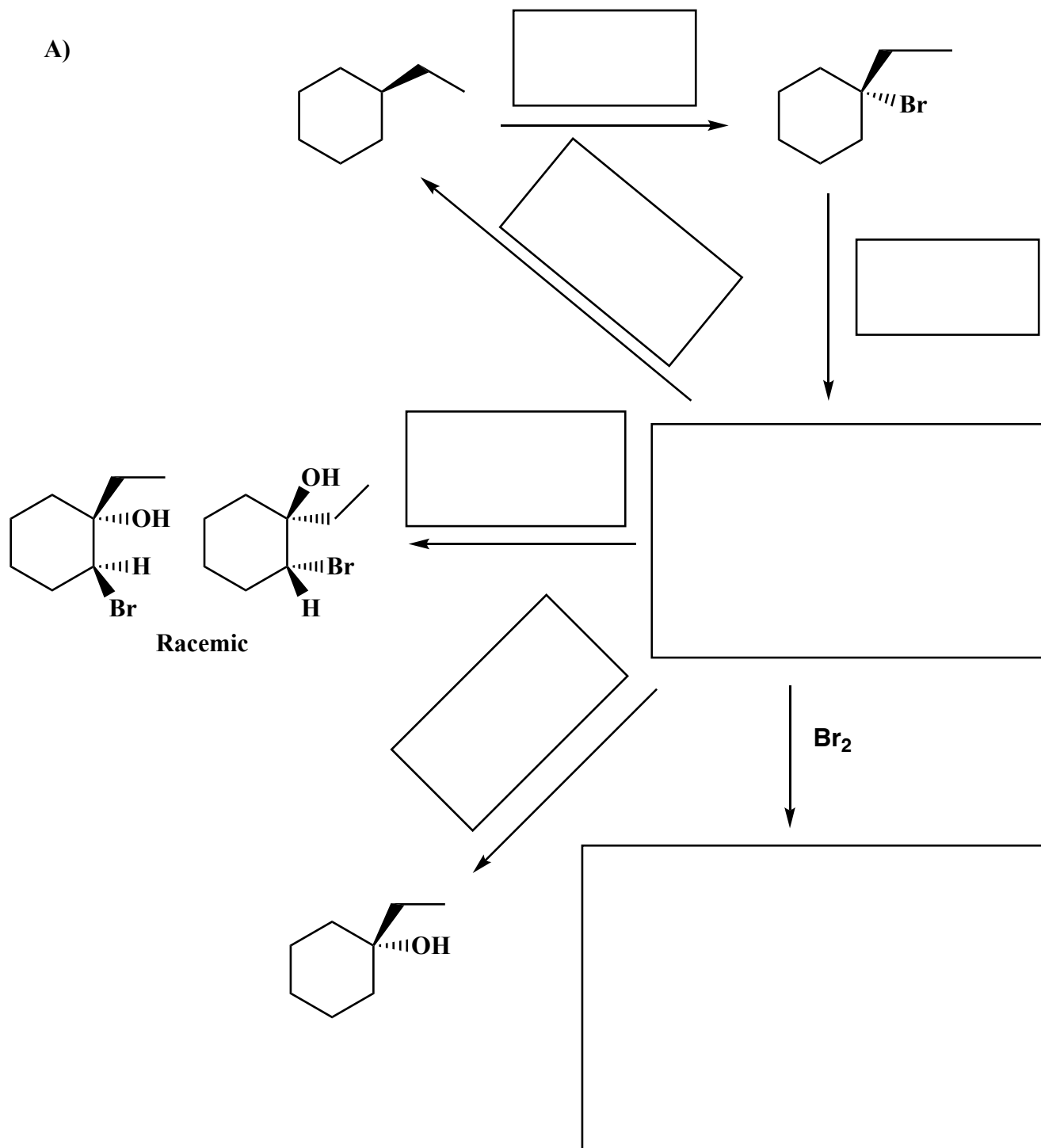
17. (3 or 5 pts each) Fill in the box with the product(s) that are missing from the chemical reaction equations. **Draw only the predominant regioisomer product or products (i.e. Markovnikov or non-Markovnikov products)** and please remember that **you must draw the structures of all the product stereoisomers 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**.



18. (3 or 5 pts each) Fill in the boxes with the starting material, reagents or product(s) that are missing from the chemical reaction equations. **Once again, for the products 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.**

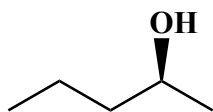
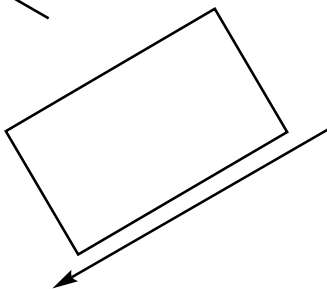
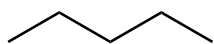
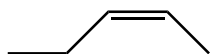
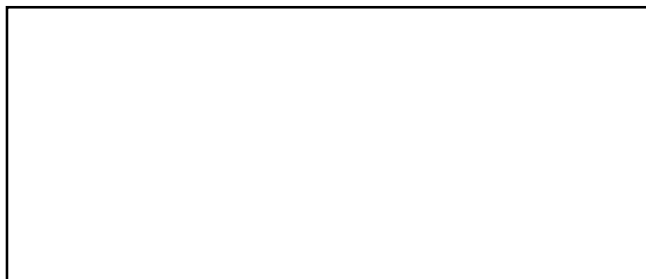


19. (18 pts) For the following reactions, fill in the box with the **predominant product(s)** or **reagent(s)** necessary to complete the following syntheses. You must indicate stereochemistry with wedges and dashes. You must use wedges and dashes to draw all stereoisomers produced as predominant products and write "racemic" under the structures when appropriate.



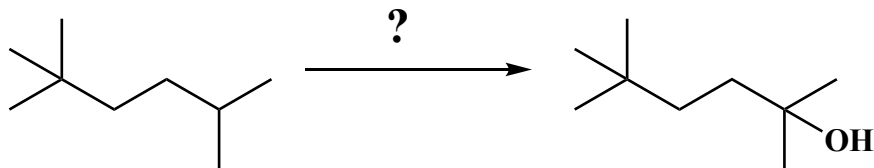
19 (cont.). (20 pts) For the following reactions, fill in the box with the **predominant product(s)** or **reagent(s)** necessary to complete the following syntheses. You must indicate stereochemistry with wedges and dashes. You must draw all stereoisomers produced as predominant products and write "racemic" under the structures when appropriate.

B)

 $\xrightarrow{\text{H}_2\text{SO}_4 \text{ (catalytic)}}$  $\xrightarrow{\text{Br}_2}$  $\xrightarrow{2 \text{ equivalents NaNH}_2}$  $\xrightarrow{\text{Br}_2}$ 

20. (7 pts) These are synthesis questions. You need to show how the starting material can be converted into the product(s) shown. You may use any reactions we have learned. Show all the reagents you need. Show each molecule synthesized along the way and be sure to pay attention to the regiochemistry and stereochemistry preferences for each reaction because only predominant products can be used. All the carbon atoms of the product(s) must come from the starting material(s) shown.

A) 7 pts



Signature _____

Pg 13 _____(13)

20 (cont.). (13 pts) These are synthesis questions. You need to show how the starting material can be converted into the product(s) shown. You may use any reactions we have learned. Show all the reagents you need. Show each molecule synthesized along the way and be sure to pay attention to the regiochemistry and stereochemistry preferences for each reaction because only predominant products can be used. All the carbon atoms of the product(s) must come from the starting material(s) shown.

B) 13 pts

