

Please read and sign the Honor Code statement below:

I pledge that on my honor, as a University of Colorado at Boulder student, I have neither given nor received unauthorized assistance on this exam.

Signature

General Instructions: There are 13 pages and 19 questions, including this cover sheet. Be sure you have them all. Read each question carefully so that you know exactly what is being asked and what you need to write or draw. Your work on scratch pages will not be graded, so be sure everything you want graded is written on the exam itself and that your answers to the multiple choice questions are correctly bubbled in on the Scantron.

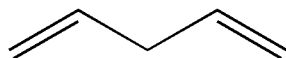
Each multiple choice question (1-15) is worth **4 points** and has **only one correct answer**. Good luck!

PERIODIC CHART OF THE ELEMENTS

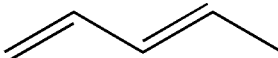
IA	IIA	IIIB	IVB	VB	VIB	VIIIB	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	INERT GASES		
1 H 1.00797														1 H 1.00797	2 He 4.0026		
3 Li 6.939	4 Be 9.0122										5 B 10.811	6 C 12.0112	7 N 14.0067	8 O 15.9994	9 F 18.9984	10 Ne 20.183	
11 Na 22.9898	12 Mg 24.312										13 Al 26.9815	14 Si 28.086	15 P 30.9738	16 S 32.064	17 Cl 35.453	18 Ar 39.948	
19 K 39.102	20 Ca 40.08	21 Sc 44.956	22 Ti 47.90	23 V 50.942	24 Cr 51.996	25 Mn 54.9380	26 Fe 55.847	27 Co 58.9332	28 Ni 58.71	29 Cu 63.54	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.9216	34 Se 78.96	35 Br 79.909	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.905	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc [99]	44 Ru 101.07	45 Rh 102.905	46 Pd 106.4	47 Ag 107.870	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.904	54 Xe 131.30
55 Cs 132.905	56 Ba 137.34	*57 La 138.91	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 196.967	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.980	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	†89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 ? (271)	111 ? (272)	112 ? (277)						

Circle the single best answer to each multiple choice question (1-15). (4 pts each)

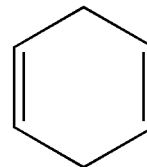
1. Which of these structures is a conjugated diene?



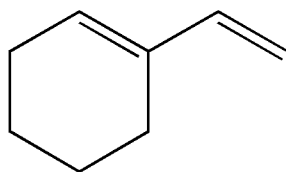
I



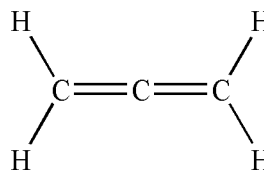
II



III

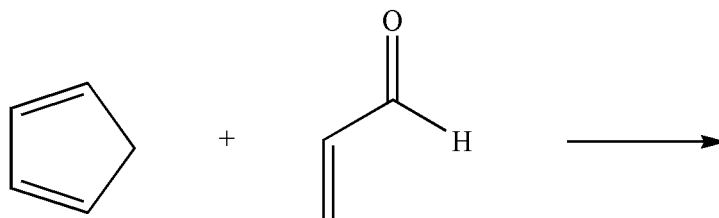


IV



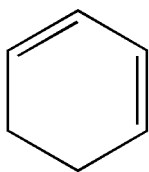
V

- a. I and III
 - b. I, III, V
 - c. II and IV
 - d. II, IV, V
 - e. All of these structures are conjugated dienes
2. Which of the following words best describes the product(s) of the following reaction?

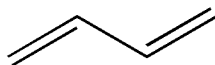


- a. constitutional isomers
- b. a single compound
- c. racemic mixture
- d. diastereomers
- e. none of these

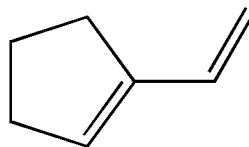
3. Which of the structures shown is in the *s-cis* conformation?



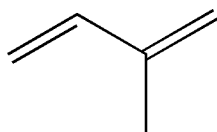
I



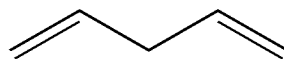
II



III



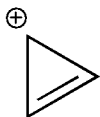
IV



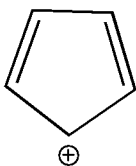
V

- a. I
- b. II
- c. III
- d. IV
- e. V

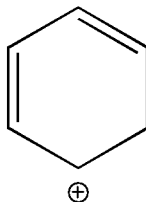
4. Which of these ions is aromatic? (Assume planarity.)



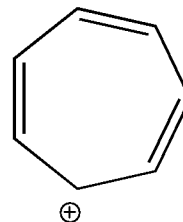
I



II



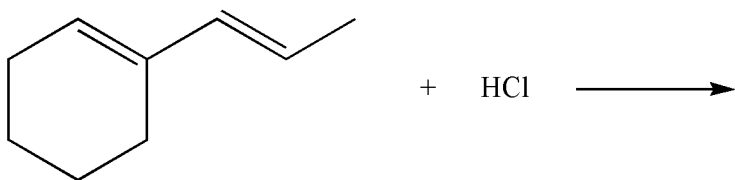
III



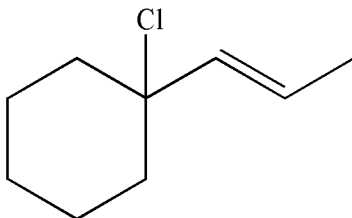
IV

- a. I
- b. II
- c. III
- d. II and III
- e. I and IV

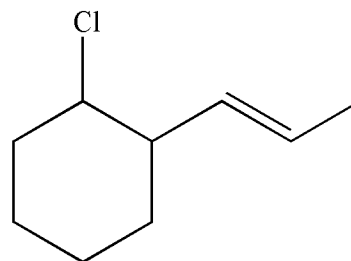
5. Which of these compounds is the thermodynamic product of the reaction shown?



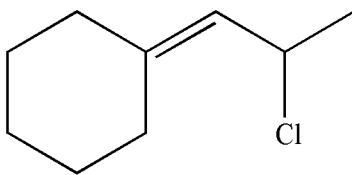
a.



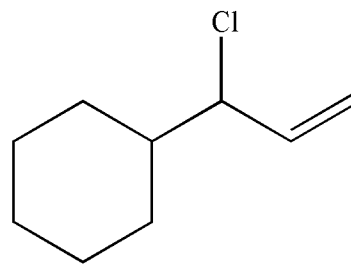
b.



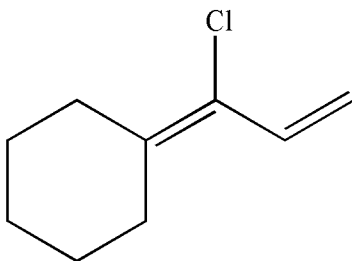
c.



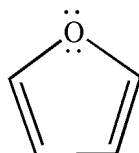
d.



e.

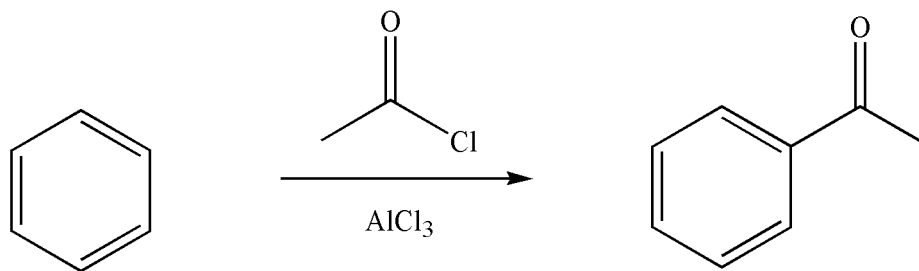


6. How many nonbonding π molecular orbitals are there in furan?

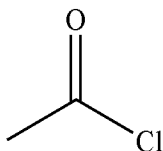


- a. 0
- b. 1
- c. 2
- d. 3
- e. 5

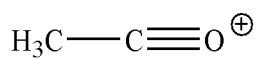
7. What is the electrophile in this reaction?



a.



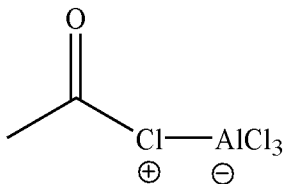
b.



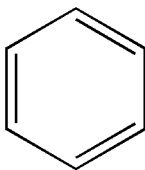
c. Benzene

d. AlCl_3

e.



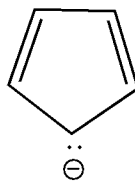
8. Which of these structures is **not** aromatic? (Assume planarity.)



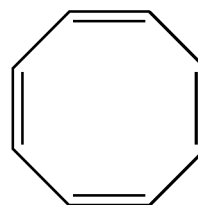
I



II



III



IV

a.

I

b.

II

c.

II and III

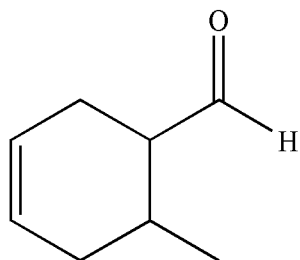
d.

II, III, and IV

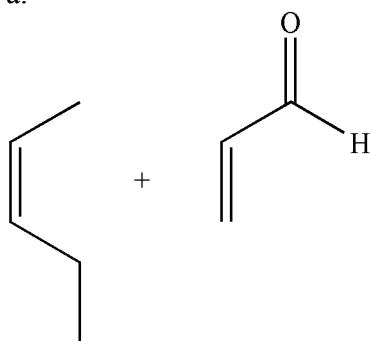
e.

II and IV

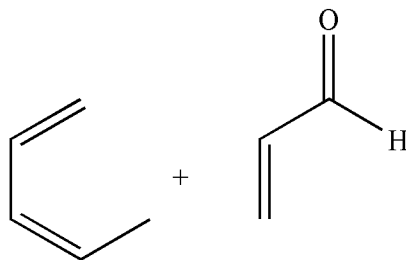
9. Which pairing of diene and dienophile would lead to the product shown?



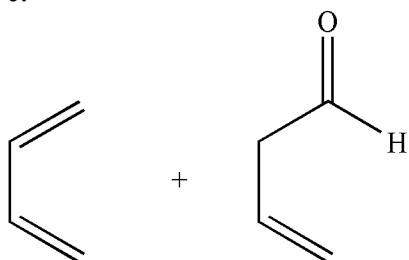
a.



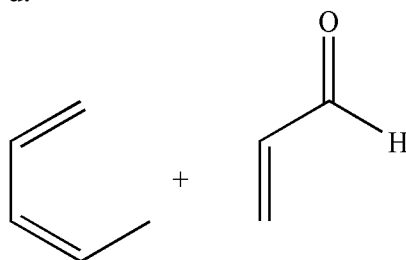
b.



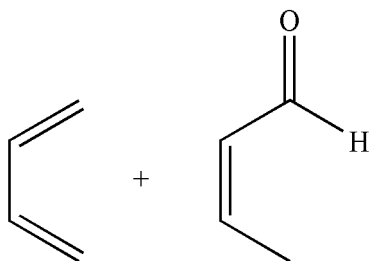
c.



d.

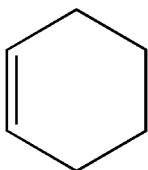


e.

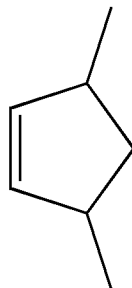


10. Which of these molecules could **not** be made using a Diels-Alder reaction?

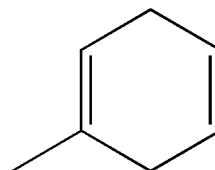
a.



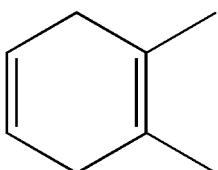
b.



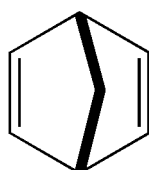
c.



d.



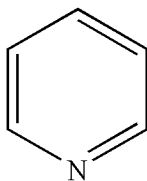
e.



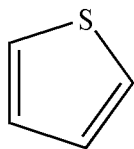
11. Which of these conditions is **not** a requirement for aromaticity?

- a. Planarity
- b. $(4n)$ π electrons
- c. Conjugation
- d. Cyclic
- e. $(4n + 2)$ π electrons

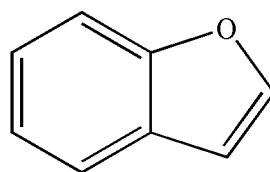
12. Which of the following compounds has at least one lone pair in an sp^2 orbital?



I



II

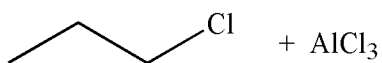


III

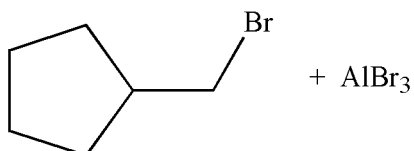
- a. I
- b. I and II
- c. I and III
- d. II and III
- e. I, II, and III

13. Which of the following substrates (i.e., starting materials) would **not** provide a rearranged product when reacted with benzene in a Friedel-Crafts alkylation reaction?

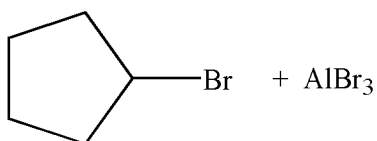
a.



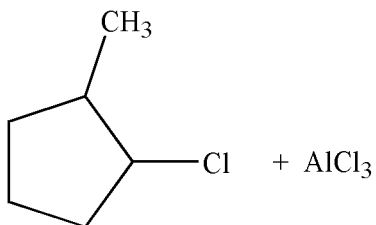
b.



c.



d.



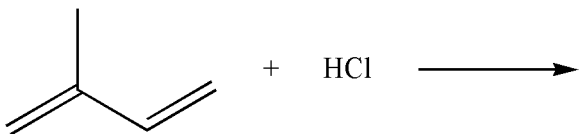
e.

All of these starting materials would rearrange.

14. Which of the following statements is **false**?

- a. All C-C bonds in benzene have the same length.
- b. Alternating C-C bonds in benzene have different lengths.
- c. Benzene does not undergo Diels-Alder reactions.
- d. Hydrogenation of benzene is slow and requires extreme conditions.
- e. The double bonds in benzene are conjugated.

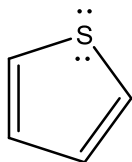
15. Which of the following statements about this reaction is **true**?



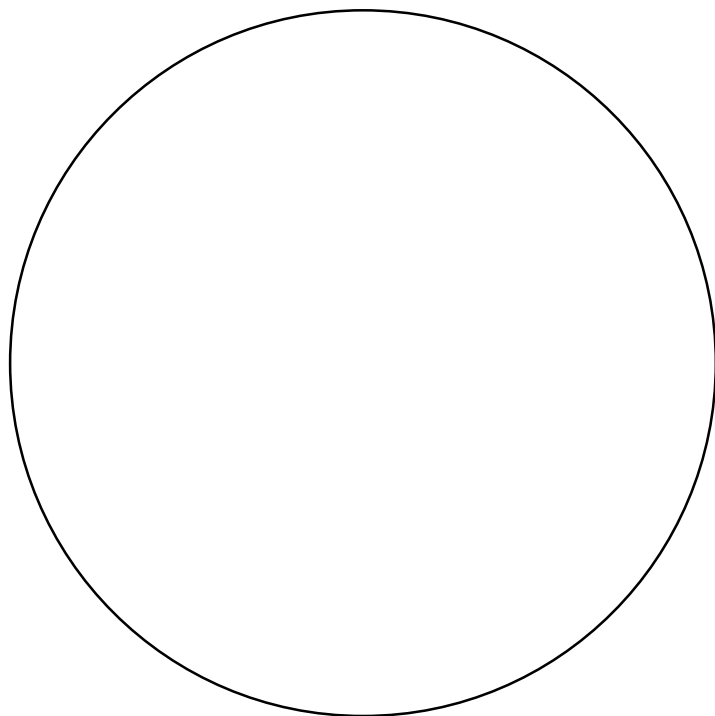
- a. The major product under kinetic conditions is the 1,2 addition product because of the stability of the carbocation intermediate in that pathway.
- b. The major product under kinetic conditions is the 1,2 addition product because of a proximity effect.
- c. The major product under kinetic conditions is the 1,4 addition product because of the stability of the carbocation intermediate in that pathway.
- d. The major product under kinetic conditions is the 1,4 addition product because of a proximity effect.
- e. Neither carbocation stability nor a proximity effect play a role in determining the preferred product under kinetic conditions.

16. Draw a Frost circle for a compound called thiophene (the circle is provided). (12 pts)

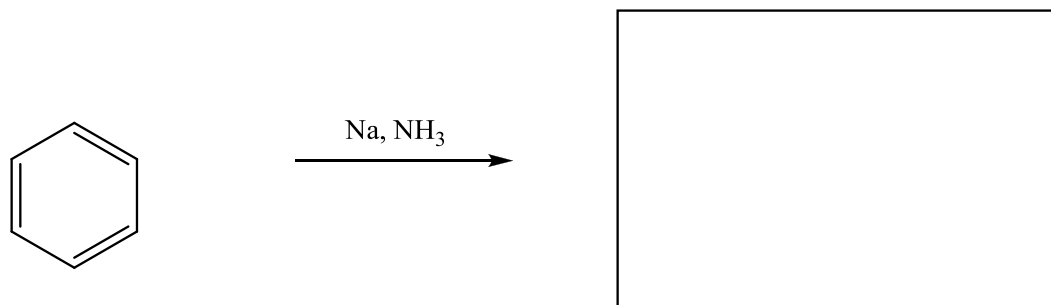
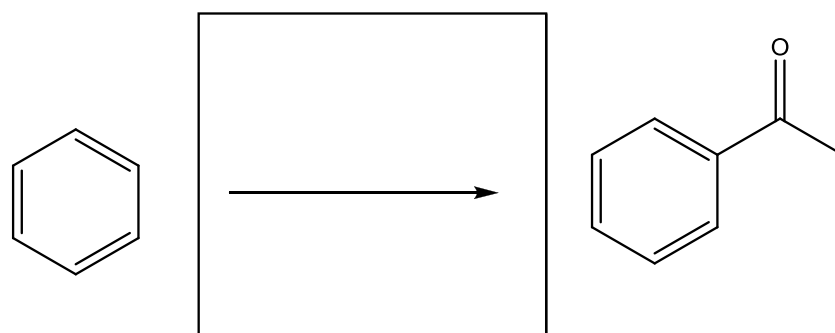
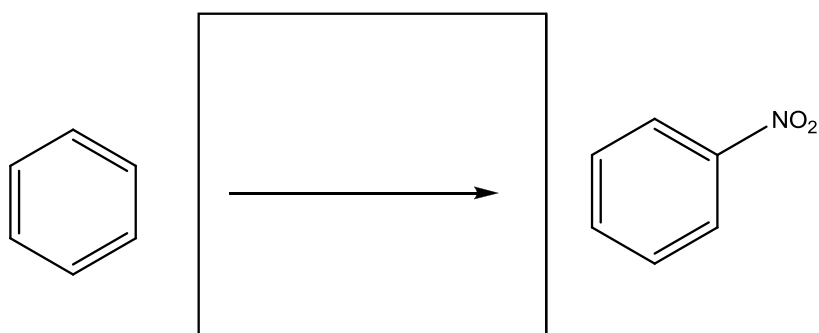
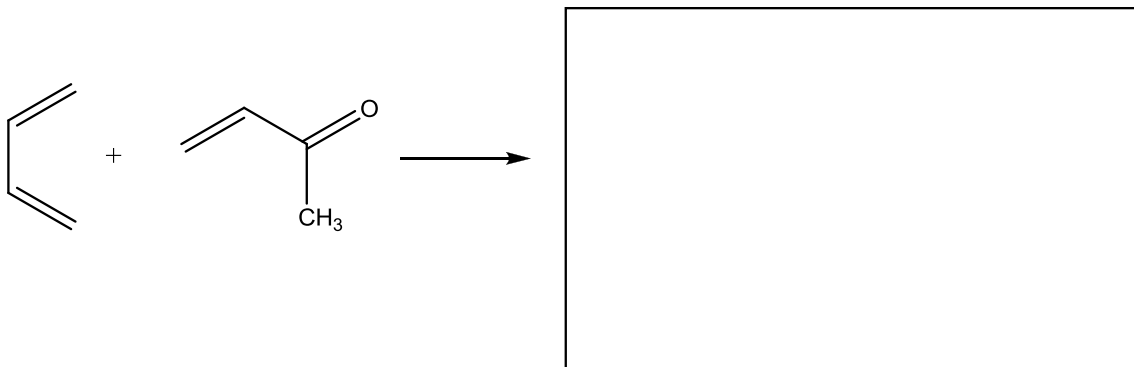
- Include and label any and all bonding, nonbonding, and antibonding molecular orbitals.
- Indicate the nonbonding energy level.
- Put the correct number of electrons in the appropriate orbitals in your drawing.
- Is this compound aromatic? Circle your answer: **Yes** **No**



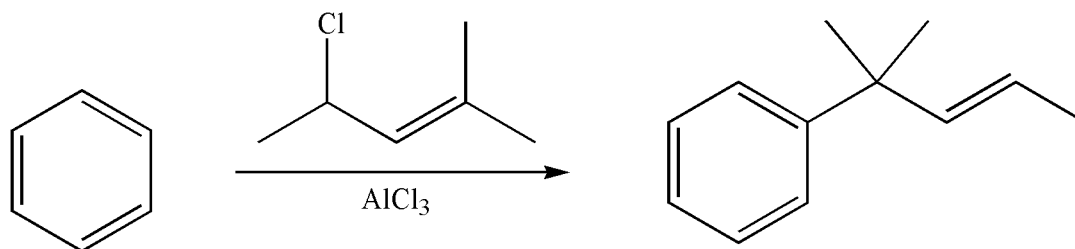
thiophene



17. Predict the products or supply the missing reagents for each of the following transformations. If more than one product forms, draw each of them. Show stereochemistry in the products where appropriate. (16 pts)



18. Draw a mechanism to illustrate the following transformation. Include all necessary lone pairs, curved arrows, and nonzero formal charges. (12 pts)



19. Design a multistep synthesis for each of the transformations shown. You may use any organic or inorganic reagents. Show the reagents needed for each step and the product of each step. Do not just give a list of reagents between starting material and target, or you will not receive full credit. (10 pts)

