This test consists of a combination of multiple-choice and other questions. There should be 25 questions on eight pages. Do not use your own tables, scratch paper, or other information. A periodic table and other information will be provided. Please turn off all cell phones and other devices that could make noise or vibrate. No food. No gum. No calculators. The test will end two hours and 15 minutes after it starts. You may use a template (stencil) and calculator. No sharing of stencils or calculators once the exam starts. You may not use molecular models.

**Multiple-Choice Questions.** These 15 questions are worth three points each, for a total of 45 points. There is only one answer per question unless stated otherwise for a given problem. Answer each question by bubbling in the letter(s) corresponding to the correct choices on the provided answer sheet. If more than one answer is correct, bubble in all of the correct ones. It is not necessary to show work for these questions and, in fact, it will be ignored. You may write on the exam.

1. Use the reaction coordinate diagram below to answers the questions that follow. More than one answer may be correct.
   - a. The equilibrium constant, \( K \), is less than one (\( K < 1 \)).
   - b. This could be an E1 reaction.
   - c. The first transition state looks more like the intermediate than it does the reactant.
   - d. None of them

2. Each of the following processes is exothermic. Which one has the more negative value for \( \Delta H \)?
   - a. \( \text{C} + :\text{Cl} \rightarrow \text{Cl} + \text{H} \cdot \text{Cl} \)
   - b. \( \text{Cl} + \text{H} \rightarrow \text{Cl} + \text{H} \cdot \text{Cl} \)
   - c. They have the same \( \Delta H \) because both involve breaking a C-H bond and making a Cl-H bond.

3. Which of the following is expected to react the fastest in a S\textsubscript{N}1 reaction with MeOH?
   - a. \( \text{Br} \)
   - b. \( \text{I} \)
   - c. \( \text{Cl} \)
   - d. It is impossible to tell

4. In which solvent will 1-bromobutane react faster with NaSH?
   - a. \( \text{OH} \)
   - b. \( \text{N} \cdot \text{O} \)
   - c. It doesn’t matter.
5. Which of the following will react fastest in an E2 reaction with NaOMe?

   a. ![Structure A]
   b. ![Structure B]
   c. ![Structure C]
   d. ![Structure D]
   e. none

6. Which of the following is/are true statements concerning the reaction below? More than one answer may be correct.

   ![Reaction](image)

   a. The rate law for the reaction is as follows: Rate = k[RBr][R'O-]
   b. The major product is alkene (2) when the base is NaOMe (R' = methyl).
   c. The major product is alkene (2) when the base is t-BuOK (R' = tert-butyl).
   d. None of the statements is true.

7. The proton NMR spectrum of one of the two products formed in the reaction in question #6 appears below. Which product corresponds to the spectrum? The integration of the proton NMR is not shown because you don’t need this information.

   ![NMR Spectrum](image)

   a. alkene (2)  
   b. alkene (1)  
   c. It is impossible to tell

8. Which of the following will have an (M+1)^+ signal with the greatest relative abundance (intensity) compared to its M^+ peak? For the purpose of this exercise it might be easiest if you think of the relative intensity of the molecular ion peak (M^+) as being 100 for each compound.

   a. 1-octene  
   b. 2-hexene  
   c. 2-bromopentane  
   d. it is impossible to tell

9. Which of the following corresponds to the most likely base peak in the mass spectrum of the molecule whose molecular ion is shown immediately below? If the first two structures seem perplexing they are an ethyl radical and an isopropyl radical.

   ![Mass Spectrum](image)

   a. ![Structure E]
   b. ![Structure F]
   c. ![Structure G]
   d. ![Structure H]
   e. none
10. Which of the following is/are the mass spectrum of a molecule that contains one bromine (and other atoms, possibly even other heteroatoms)? More than one answer may be correct. Only the molecular ion and higher mass—(M+1)^+,(M+2)^+etc.—peaks are shown; therefore, the lowest-mass peak corresponds to the molecular ion.

a. none

b. c.

d. none

11. Which of the following compounds corresponds to the proton NMR spectrum below?

a. 

b. 

c. 

d. 

12. Which compound matches the carbon NMR below? The spectrum is broad band only.

a. 

b. 

c. 

d. 

e. 

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13. Which of the following is/are expected to rearrange if formed? More than one choice may be correct

a. ![Chemical Structure A]  
b. ![Chemical Structure B]  
c. ![Chemical Structure C]  
d. none

14. The compound on the left reacts more rapidly than the one on the right with NaSCH$_3$ in acetone. Which acid is stronger?

![Chemical Structures](Cl, O=S, HO=S)  
a. HCl  
b. ![Chemical Structure D]  
c. It is impossible to tell.

15. Which of the following is the major elimination product of the reaction shown?

![Chemical Structure](OTs, NaOMe)  
a. ![Elimination Product A]  
b. ![Elimination Product B]  
c. ![Elimination Product C]  
d. ![Elimination Product D]  
e. none
Matching. The following four questions are worth two points each, for a total of eight points. For each question match its spectrum to one of the structures and answer by using the letter corresponding to the appropriate structure. Answer these questions on the Zip-Grade form. No work or justification is necessary.
Other Questions Each of the following questions is worth the indicated number of points, for a total of 47 points. Please be sure that you provide all of the information requested for each.

20. 3 points Name the compound below, using one of the naming systems discussed in class. Circle or put a box around your final answer.

![Compound](image)

21. 12 points For each of the following reactions, draw the structure of the major organic product and give the name of the mechanism (S\(_N\)1, S\(_N\)2, E1, E2) that produced it.

   a. \( \text{CH}_3\text{OH} \xrightarrow{\text{HBr}} \)

   b. \( \text{C}_6\text{H}_{10} \xrightarrow{\text{DBU}} \)

   c. \( \text{CH}_3\text{OTs} \xrightarrow{\text{NaSCH}_3} \)

   d. \( \text{CH}_3\text{Br} \xrightarrow{\text{CH}_3\text{OH}} \)

22. 6 points Write the mechanism for the following reaction, following the protocol we used in class. This means that you include curved arrows and structures of intermediates with formal charges shown. The concentrated sulfuric acid is aqueous and, thus, contains water.

   ![Reaction](image)
23. **6 points** Draw a series of reactions that shows how the final product shown could be prepared, starting from the reactant given. In addition to the reactant you may use any inorganic reagents and any organic reagents whose carbons don’t end up in the final product. Show structures of any intermediate products that could be isolated.

![Reaction Diagram]

24. **6 points.** Determine and draw the structure of the compound with molecular formula C\text{\textsubscript{11}}H\text{\textsubscript{14}}O whose carbon NMR spectrum is shown. DEPT-135 information is shown above each signal in the broad band spectrum provided. While this is the spectrum of one, specific compound, there is more than one structure that could be determined from the spectrum as given. Show work and/or logic and box or circle your final answer.

![NMR Spectrum]
25. **6 points** Complete the mechanism below by adding curved arrows to show electron movement.

![Mechanism Diagram]

26. **8 points** Determine the molecular formula of the compound that has the infrared and mass spectra below. In the mass spectrum only the molecular ion and higher mass signals are shown. Show work and logic clearly and box or circle your final answer.

![Mass Spectra and IR Spectra]