Instructions: This is a closed book examination. You may not use any notes, books or external materials during the course of the examination. Please print your name and social security number on the front page of the examination. Be sure to allot your time in a manner that is related to the point value of the question. Be sure to show your reasoning wherever possible for partial credit.

All material to be graded must be on one of the pages of the exam with your name and social security number on the front page. If you need more space than is available on the page with the questions, use the back page of the previous page and label the number of the question on that page.

Notice that all questions are worth exactly the same number of points.

Correlation tables for IR, $^1$H NMR and $^{13}$C NMR are attached on the last page of the exam.

Your Name: ____________________________________________

Your Soc. Sec. Number: __________________________________

Time for the exam: three hours.

Question 1: 20 points _______________
Question 2: 20 points _______________
Question 3: 20 points _______________
Question 4: 20 points _______________
Question 5: 20 points _______________
Question 6: 20 Points _______________
Question 7: 20 Points _______________
Question 8: 20 Points _______________
Question 9: 20 Points _______________
Question 10: 20 Points _______________
Question 11: 20 Points _______________
Question 12: 20 Points _______________
Question 13: 20 Points _______________
Question 14: 20 Points _______________
Question 15: 20 Points _______________

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Total: 300 Points
1. (20 Points). Which of the compounds in each of the following groups are isomers?

(a) Butane, cyclobutane, isobutane, 2-methylbutane

(b) Cyclopentane, neopentane, 2,2-dimethylpentane, 2,2,3-trimethylbutane

2. (20 Points). (a) Evidence from a variety of sources indicates that cyclopropyl cation is much less stable than isopropyl cation. Why?

(b) The cation CF₃CHCH₃ is much less stable than isopropyl cation. Why?

3. (20 Points) Draw the structure of the major product expected of each of the following reactions.

(a) \[
\begin{array}{c}
\text{hv} \\
\text{Br}_2
\end{array}
\]

(b) \[
\begin{array}{c}
\text{OH} + \text{HBr}
\end{array}
\]
4. **(20 Points)** Menthol and neomenthol are constitutional isomers possessing the Lewis structure A. Menthol is the most stable stereoisomer possessing the constitution A and neomenthol is the next most stable stereoisomer possessing the Lewis structure A.

(a) Draw a structure clearly showing the axial and equitorial positions of the substituents in menthol. (Hint: A hydroxy group is a smaller group than a methyl group.)

(b) Are the hydroxy and methyl groups cis or trans to each other in menthol?

d) Are the hydroxy and methyl groups cis or trans to each other in neomenthol?
5. **(20 Points)** Which of the following structures are chiral? Indicate your reasoning for full credit.

![Chemical structures A, B, C, and D]

6. **(20 Points)** Treatment of either of the 1,2-bromoalcohols A or B with HCl results in formation of the 1-bromo-2-chloro cyclopentane C, but the rate of reaction of A to form C is much faster than the rate of reaction of B to form C. Suggest a plausible mechanistic interpretation of these results.

![Chemical reaction diagram A to C and B to C]
7. **(20 Points)**. Treatment of neomenthyl chloride A with strong base results in a rapid reaction to produce B as the major product, while treatment of methyl chloride C results in a very slow reaction to produce D as the major product. Suggest a plausible mechanistic interpretation of these results. A chlorine atom possesses a smaller van der Waals diameter than a methyl group.

```
CH₃
CH(CH₃)₂

A

Cl
CH(CH₃)₂

CH₃
CH(CH₃)₂

B

Fast

RO⁻

CH₃
CH(CH₃)₂

C

Cl
CH(CH₃)₂

CH₃
CH(CH₃)₂

D

Slow

RO⁻
```
8. (20 Points.) Suggest plausible syntheses, employing only known synthons, starting with the indicated starting material. More than one synthetic step may be required. You may use any inorganic reagents you require in any step.

A \[\begin{array}{c}
\text{？}
\end{array}\] \[\begin{array}{c}
\text{HC-CH}_{2}-
\end{array}\] \[\begin{array}{c}
\text{CH}_{3}
\end{array}\]

9. (20 Points). Suggest structures of the diene and dienophile you would employ to synthesize the following Diels Alder products.
10. (20 Points) Suggest a plausible synthesis for the indicated compounds employing the indicated starting material and any inorganic or organic reagents you need in addition to the starting material. More than one step may be required for a plausible synthesis.

(A) \[
\text{CH}_3\ \text{OH} \\
\text{H} \\
\text{H} \\
\downarrow
\]

(B) \[
\text{CH}_3\ \text{OH} \\
\text{H} \\
\text{H} \\
\downarrow
\]

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11. (20 Points) Suggest a plausible structure for \( \text{C}_4\text{H}_8 \) (A) and \( \text{C}_{10}\text{H}_{16} \) (B) based on the indicated reactions. Be sure to indicate pertinent stereochemistry in the structures you suggest.

(A) \( \text{C}_4\text{H}_8 \) \[\xrightarrow{\text{Cl}_2}\] \( \text{CH}_3\text{Cl} \)

(B) \( \text{C}_{10}\text{H}_{16} \) \[\xrightarrow{1. \text{O}_3}\] \[\xrightarrow{2. \text{H}_2\text{O}}\] \( \text{O} \text{O} \text{CH} \text{CH} \text{CH} \text{CH} \text{H} \)
12. (20 Points) Compound A \((C_7H_{13}Br)\) is a tertiary bromide. On treatment with sodium ethoxide in ethanol, A is converted to a hydrocarbon B \((C_7H_{12})\). Ozonolysis of B gives C as the only product. Deduce the structures of A and B.

\[
\begin{align*}
A \quad &\quad \text{CH}_3\text{CH}_2\text{O}^- \quad \text{B} \quad &\quad 1. \text{O}_3 \\
\text{CH}_3\text{CH}_2\text{O}^- \quad &\quad \text{B} \quad &\quad 2. \text{H}_2\text{O}, \text{Zn} \\
\end{align*}
\]

13. (20 Points) Which of the following bromides will undergo nucleophilic substitution more rapidly under \(S_N1\) conditions? Explain your reasoning.

(A) \(\text{O}_2\text{N-CH}_2\text{Br}\)  \(\text{CH}_3\text{O-CH}_2\text{Br}\)  
(B) \(\text{CH}_3\text{O-CH}_2\text{Br}\)  

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14. **(20 Points)** Consider that the infrared carbonyl stretching frequencies of the three compounds A, B, and C are quite different. Based on your knowledge of resonance theory and infrared spectroscopy, predict which will have the highest carbonyl stretching frequency and which will have the lowest carbonyl stretching frequency. Explain your reasoning.

![Chemical structures](image1.png)

15. **(20 Points, 10 Points for each spectrum)** Suggest a structure that is consistent with the $^1$H NMR and $^{13}$C NMR spectra shown on the following pages for the molecular compositions $A = C_8H_{14}O_4$, $B = C_9H_{10}O$. Both A and B show a strong IR absorption around 1700 cm$^{-1}$. Indicate briefly how each structure is consistent with the proton spectrum and the $^{13}$CNMR spectrum.

The suggested structure for A is

![Chemical structure](image2.png)
My reasoning for suggesting the structure for A:

The suggested structure for B is

My reasoning for suggesting the structure of B is