If you do not want your graded exam placed in the box outside my office, then please tick here__________

1) (5pts total) Give one definition of a Nucleophile

b) Give one definition of an Electrophile

c) Give one definition of an acid.

2) Briefly explain what is meant the following terms:(16pts total)
Unsaturated Compound

Chiral Molecule

Racemic Mixture

Rate Determining Step

Anti Addition

Thermodynamics

Kinetics

\(\pi\) bond
3) Name the classes of compound that the following molecules belong to (E.g. alkane, amide, etc). (15pts)

\[
\begin{align*}
\text{R-O-O-R} & \quad \text{R-O-R} & \quad \text{R-O-H} \\
\text{O} & \quad \text{O} & \quad \text{O} \\
\text{R-O-H} & \quad \text{R} & \quad \text{R} \\
\end{align*}
\]

\[
\begin{align*}
\text{R} & \quad \text{R} \\
\text{O} & \quad \text{O} \\
\end{align*}
\]

4) Draw Lewis structures (sticks for bonds, and dots for lone pairs) for the below two molecules. (10pts)

\[
\begin{align*}
\text{Br} & \quad \text{H} & \quad \text{O} \\
\end{align*}
\]

\[
\begin{align*}
\text{R} & \quad \text{R} \\
\text{O} & \quad \text{O} \\
\end{align*}
\]

5) For the previous two molecules, label the hybridization of all the carbons. (5pts)
6) Classify each of the following reactions as an Elimination, Addition or Substitution. (5pts)

(a) \( \text{OH} \quad \rightarrow \quad \text{Br} \)

(b) \( \text{H}_3\text{C} = \text{CH}_3 \quad \rightarrow \quad \text{H}_3\text{C} = \text{H} \)

(c) \( \text{Ph} = \text{Ph} \quad \rightarrow \quad \text{Ph} = \text{Ph} \)

(d) \( \text{H}_3\text{C} = \text{CH}_3 \quad \rightarrow \quad \text{H}_3\text{C} = \text{CH}_3 \)

(e) \( \text{H}_3\text{C} - \text{CH}_2\text{OH} \quad \rightarrow \quad \text{H}_3\text{C} - \text{CH}_2\text{Br} \)

7) Explain (including curly arrows) why in this electrophilic addition reaction, none of product A is generated, and product B is formed exclusively. (9pts)

\[ \text{H}_3\text{C} - \text{CH}_3 + \text{H-Cl} \rightarrow \text{H}_3\text{C} - \text{CH}_3 \]

Product A \( \times \) Product B
8) Draw an energy level diagram for a typical endothermic S_N_1 process. Make sure to label (a) the axes (b) the reactants and products (c) any transitions states (d) ΔH° for the overall reaction (e) the rate determining step and (f) the cation (9pts)

9) By considering the hybridization of the central atom, predict the shapes and bond angles of CH_3^+ and CH_4. (10pts)
10) Name the following molecules in IUPAC form. (16pts)

(a)

(b)

(c)

(d)

(e)
11) Assign R or S to each chiral center in these molecules. (12pts)

(a) 
\[
\begin{array}{c}
F \\
\text{H}_3\text{C} \text{Cl} \text{NH}_2
\end{array}
\]

(b) 
\[
\begin{array}{c}
F \\
\text{H}_2\text{C} \text{H}
\end{array}
\]

(c) 
\[
\begin{array}{c}
\text{H} \\
\text{H}_3\text{C} \text{Cl} \text{Cl}
\end{array}
\]

(d) 
\[
\begin{array}{c}
\text{CO}_2\text{H} \\
\text{Br} \text{H} \text{Cl} \text{H} \text{CF}_2\text{H}
\end{array}
\]

12) What is the name of this type of Projection (2pts).

(b) What is meant by the term *diastereomer*? (2pts)
13) (i) Write a mechanism (i.e. curly arrows) for this E1 elimination. (8pts)

\[
\begin{array}{c}
\text{Br} \\
\text{K}^+\text{OCH}_3, \text{CH}_3\text{OH} \\
\rightarrow \\
\text{alkene}
\end{array}
\]

(ii) There is also another (minor) product that is formed from elimination, draw this product. (2pts)

14) The most stable conformation for a cyclohexane ring bearing an ethyl group is a “chair conformation with the ethyl group equatorial”.

(i) Explain and draw what the chair conformation is (5pts)

(ii) Explain what ‘equatorial’ is (3pts)
(iii) Explain why it is energetically preferred to put the substituent equatorial. (6pts)

15) Answer the following:
(i) State two characteristics of an E2 reaction. (2pts)

(ii) State two characteristics of an SN2 reaction. (2pts)

(iii) Explain the difference between stereoisomers and structural isomers. Provide an example of both types. (6pts)
16) Give the reagents for 5 of the 6 following reactions of cyclohexene. (15pts)

16b) Write the mechanism for one of the preceding reactions. (10pts)
17) Give the products in **5 of the 6** following transformations. (15pts)

17b) Write the mechanism for **one** of the preceding reactions. (10pts)
**Bonus question** (up to 5 points).
List up to 5 of your favorite (or most annoying) phrases or sayings that Dr. Roche repeatedly used throughout the semester.
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1) (5pts total) Give one definition of a Nucleophile
   Two electron donor; Lewis base
b) Give one definition of an Electrophile
   Electron pair acceptor; Lewis acid
c) Give one definition of an acid.
   \[ \text{H}^+ \text{ donor dissolves to give } \text{H}^+; \text{ electron pair acceptor} \]

2) Briefly explain what is meant by the following terms: (16pts total)
   Unsaturated Compound
   Does not have the maximum number of bonds to Hydrogen, meaning either 
   \[ \text{IT bonding or a ring} \]
   Chiral Molecule
   It has a non-superimposable mirror image.
   Racemic Mixture
   A mixture containing both enantiomers of a chiral compound
   Rate Determining Step
   The slowest step of a multistep process.
   Anti Addition
   Addition of two atoms/groups on opposite faces of a \( \pi \) bond.
   Thermodynamics
   The study of energy changes during a reaction.
   Kinetics
   The study of the rates of reaction.
   \( \pi \) bond
   Sideways overlap of \( p \) orbitals to form a bond.
3) Name the classes of compound that the following molecules belong to (E.g. alkane, amide, etc). (15pts)

- Peroxide: \( R-O-O-R \)
- Ethers: \( R-O-R \)
- Alcohol: \( R-OH \)
- Carboxylic acid: \( R-COOH \)
- Aldehyde: \( R-CHO \)
- Ester: \( R-COOR \)
- Alkene: \( R=\equiv R \)
- Peroxy acid: \( R-COOH \)
- Thiol: \( R-SH \)
- Ketone: \( R-C=O \)

4) Draw Lewis structures (sticks for bonds, and dots for lone pairs) for the below two molecules. (10pts)

5) For the previous two molecules, label the hybridization of all the carbons. (5pts)
6) Classify each of the following reactions as an Elimination, Addition or Substitution. (5pts)

(a) \[ \text{OH} \rightarrow \text{Br} \quad \text{Substitution} \]

(b) \[ \text{CH}_3 - \text{CH}_3 \rightarrow \text{CH}_2 - \text{CH}_3 \quad \text{Add} \]

(c) \[ \text{Br} \quad \text{Ph} \rightarrow \text{Ph} \quad \text{Elim} \]

(d) \[ \text{Cl} \quad \text{CH}_3 \rightarrow \text{CH}_3 \quad \text{Elim} \]

(e) \[ \text{CH}_2 - \text{CH}_2 \text{OH} \rightarrow \text{CH}_2 - \text{CH}_2 \text{Br} \quad \text{Subst} \]

7) Explain (including curly arrows) why in this electrophilic addition reaction, none of product A is generated, and product B is formed exclusively. (9pts)

Product A

This cation is primary and therefore unstable and unwilling to be generated.

Product B

This cation is tertiary, the allyl groups help stabilize the cation. This intermediate is low energy & easily formed.
8) Draw an energy level diagram for a typical \textbf{endothermic} $S_{N}1$ process. Make sure to label (a) the axes (b) the reactants and products (c) any transition states (d) $\Delta H^\circ$ for the overall reaction (e) the rate determining step \textbf{and} (f) the cation (9pts)

![Energy Level Diagram](image)

9) By considering the hybridization of the central atom, predict the shapes and bond angles of $\text{CH}_3^+$ and $\text{CH}_4$. (10pts)

$\text{H} : \text{C} : \text{H}$  
Three bond pairs  \rightarrow $sp^2$ hybridization, trigonal planar

$\text{H} \begin{array}{c} \text{C} \\ \text{H} \end{array}$  
Four bond pairs  \rightarrow $sp^3$ hybridization, tetrahedral

$\text{H} : \text{C} : \text{H}$  
0 lone pairs  \rightarrow $sp^2$ hybridization, trigonal planar

$\text{H} \begin{array}{c} \text{C} \\ \text{H} \end{array}$  
0 lone pairs  \rightarrow $sp^3$ hybridization, tetrahedral
10) Name the following molecules in IUPAC form. (16pts)

(a) 1-chloropropane

(b) 2-methyl-1-pentyne (or 4-methylpent-1-yn)

(c) anti 4-chlorocyclohexanol

(d) Z 1-bromo 4-octene (or 1-bromo oct-4-ene)

(e) anti 3-chloro-1-cyclobutene
11) Assign R or S to each chiral center in these molecules. (12pts)

(a) 

(b) 

(c) 

(d) 

12) What is the name of this type of Projection (2pts).

Newman

(b) What is meant by the term diastereomer? (2pts)

A stereoisomer which is not an enantiomer.

(same molecular formula, same connectivity, different 3D arrangement in space).
13) (i) Write a mechanism (i.e. curly arrows) for this E1 elimination. (8pts)

![Mechanism Image]

(ii) There is also another (minor) product that is formed from elimination, draw this product. (2pts)

14) The most stable conformation for a cyclohexane ring bearing an ethyl group is a "chair conformation with the ethyl group equatorial".
   (i) Explain and draw what the chair conformation is (5pts)

   ![Chair Conformation Image]

   The chair conformation has the 6 carbons arranged in this shape.

(ii) Explain what 'equatorial' is (3pts)

   ![Equatorial Image]

   The grey Hydrogens are equatorial, they point sideway away from the ring.
(iii) Explain why it is energetically preferred to put the substituent equatorial. (6pts)

Substituent equatorial, the substituent points away from the ring, removing bad steric interactions.

Substituent axial, there is steric hindrance with other axial substituents.

15) Answer the following:
(i) State two characteristics of an E2 reaction. (2pts)

Consolidated; elimination; bimolecular kinetics, needs strong base, prefers aromatic.

(ii) State two characteristics of an S_N2 reaction. (2pts)

Consolidated; substitution; bimolecular kinetics, needs good nucleophile, stereo-specific with inversion.

(iii) Explain the difference between stereoisomers and structural isomers. Provide an example of both types. (6pts)

Isomers are different compounds that have the same molecular formula.

Structural isomers have different bond connectivity, eg C6H12 = \( \text{C}_6H_{12} \) and \( \text{C}_6H_{12} \).

Stereoisomers have the same bond connectivity but differ in the spatial arrangement of atoms.

Eg \( \text{L} \) and \( \text{L} \).
16) Give the reagents for 5 of the 6 following reactions of cyclohexene. (15pts)

\[ \begin{align*}
\text{Cl} & \xrightarrow{\text{HCl}} \text{Cl} \\
\text{OH} & \xrightarrow{\text{HCl}} \text{Cl}, \text{H}_2, \text{Ni} \\
\text{Br} & \xrightarrow{\text{ROOR, H}_2\text{O}} \text{OH}
\end{align*} \]

16b) Write the mechanism for one of the preceding reactions. (10pts)
17) Give the products in 5 of the 6 following transformations. (15pts)

17b) Write the mechanism for one of the preceding reactions. (10pts)