General Instructions:

(i) Use scratch paper at back of exam to work out answers; final answers must be recorded at the proper place on the exam itself for credit. Models are allowed.

(ii) Print your name on each page.

(iii) Please keep your paper covered and your eyes on your own work. Misconduct will lead to failure in the course.

1. (10 points) Draw a structure that corresponds to each of the following names. Show all atoms in each structure, including hydrogen atoms.

(a) Z-2-bromo-2-octene

![Structure of Z-2-bromo-2-octene]

(b) 1,6-heptadiene

![Structure of 1,6-heptadiene]
2. (16 points) CFCI$_3$ was one of the first widely-used refrigerants, but it is very harmful to Earth’s ozone layer. Therefore, this compound was replaced by CHFCl$_2$, which is less destructive to the ozone layer; however, CHFCl$_2$ is now in disfavor because it has a strong greenhouse effect (causes global warming). Answer the questions below.

(a) Provide a drawing of CHFCl$_2$ that indicates the three-dimensional structure.

(b) Indicate the F-C-Cl bond angle (approximation) in the box.

(c) Provide an energy diagram that shows how the relevant atomic orbitals combine to form the molecular orbitals of one C-Cl bond, and where the bonding electrons are expected to reside. Assume that Cl is sp$^3$ hybridized.

Atomic orbital

Molecular orbitals

Total for 2e = +8

$2e^5$ in $\sigma = +2$

$\sigma$ is lowest = +2
3. (12 points) For each equilibrium shown below, do two things:

(i) Put a SQUARE around the STRONGER BASE, of the two species that are serving as bases in the equilibrium.

(ii) Put a CIRCLE around the SIDE of the equilibrium that you expect to be MORE FAVORED.

(a) \[
\text{CH}_4 + K \cdot \text{OH} \rightleftharpoons K \cdot \text{CH}_3 + \cdot \text{OH}_2
\]

(b) \[
\begin{array}{c}
\text{Cl} \\
\text{Cl} \\
\text{OH}
\end{array}
+ \begin{array}{c}
\text{Cl} \\
\text{H} \\
\text{O} \\
\text{Na}
\end{array}
\rightleftharpoons \begin{array}{c}
\text{Cl} \\
\text{Cl} \\
\text{Na} \\
\text{OH}_2
\end{array} + \begin{array}{c}
\text{Cl} \\
\text{H} \\
\text{O}
\end{array}
\]

(c) \[
\begin{array}{c}
\text{NH}_3 \\
\text{Br}
\end{array}
+ \begin{array}{c}
\text{NH}_2 \\
\text{CH}_3
\end{array}
\rightleftharpoons \begin{array}{c}
\text{NH}_2 \\
\text{Br}
\end{array} + \begin{array}{c}
\text{NH}_3 \\
\text{CH}_3
\end{array}
\]
4. (25 points)

(a) Draw the energy diagram for rotation about the indicated carbon-carbon bond (dotted arrow) of the molecule shown below. Draw appropriate chemical structures for each minimum and each maximum in the energy function.

CIRCLE the most stable structure(s).

NOTE: A methyl group is larger (causes more steric repulsion) than a Cl atom.

- 2 pts for incorrect en. placement (min vs max)

Most stable
5. (12 points) Provide a mechanism ("curved arrows") for the reaction shown below. You do **not** have to account for the way that $H_3O^+$ is formed. Show every atom in each structure you draw.

- 4 points for each arrow
- 1 point for each intermediate
- **3 points for each intermediate**
- 1 point for rearrangement to same
- 1 point for each intermediate as skeletal
- **1 point** no $\Theta$ on hydronium
- no points awarded after $\Theta$ OH attack / elimination
6. (25 points)

Draw FIVE isomers with the formula C₇H₁₄ that would ALL give the same major product upon reaction with HCl (without any rearrangement) and that would ALL generate 3-methylhexane upon reaction with H₂ and Pd/C.

+5 for each correct structure