1. (6 points) Write two resonance structures for acetamide by putting in all appropriate π-bonds, lone pairs of electrons, and formal charges. **CIRCLE** the most important resonance contributor.

![Acetamide resonance structures](image)

2. (6 points) Protonation of 2-methyl-1,3-butadiene (isoprene) occurs mainly at carbon 1 to produce the allylic cation whose carbon skeleton is drawn below. Write the two best resonance structures for this cation by putting in all appropriate π-bonds, lone pairs of electrons, and formal charges **CIRCLE** the most important resonance contributor.

![Allylic cation resonance structures](image)

3. (6 points) Two steroids are shown below. Closely examine the molecules to determine the functional groups present. A number of oxygen containing functional groups are listed below each molecule. **CIRCLE** the functional groups present in each of the compounds.

- **Testosterone**
  - Alcohol
  - Ether
  - Aldehyde
  - Ketone
  - Carboxylic Acid
  - Ester

- **Cholic Acid**
  - Alcohol
  - Ether
  - Aldehyde
  - Ketone
  - Carboxylic Acid
  - Ester
4. (6 points) A Newman projection looking down the C2-C3 bond of (2R,3R)-2-bromo-3-chlorobutane is drawn below. Draw Newman projections of two other staggered conformations of this molecule. **CIRCLE** any conformation in which there is an antithetical relationship between hydrogen and bromine.

(2R,3R)-2-bromo-3-chlorobutane

5. (a) (4 points) Write the structure of 2-chloro-4-ethyl-2-methylhexane **show all carbons and hydrogens**.

\[
\begin{align*}
\text{H}_2\text{C} & \quad \text{C} \quad \text{C}_2\text{H}_5 \\
& \quad \text{CH}_3 \\
& \quad \text{Cl} \\
\text{CH}_3 & \quad \text{CH}_2 & \quad \text{CH}_2 & \quad \text{CH}_3
\end{align*}
\]

(b) (4 points) Write the structure of para-bromobenzoic acid **show all atoms**.

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

(c) (6 points) How many (π-bonds + rings) does \( \text{C}_9\text{H}_8\text{O}_2 \) have? **Write the structure of a compound with the formula \( \text{C}_9\text{H}_8\text{O}_2 \) that has both an ester and an ether functional group.**

\[
\begin{align*}
\text{CH}_3 & \quad \text{O} \quad \text{CH}_2\text{CH}_3 \\
\text{H} & \quad \text{H} \\
\text{O} & \quad \text{C} \quad \text{H}_2\text{CH}_3 \\
\text{OH} & \quad \text{H} \\
\text{CH}_3 & \quad \text{O} \quad \text{CH}_2\text{CH}_3
\end{align*}
\]
6. (a) (9 points) Draw the most stable chair conformation of trans-1,4-dimethylcyclohexane clearly showing all hydrogens. **CIRCLE** one axial hydrogen and draw a **BOX** around one equatorial hydrogen.

![Chemical structure](image)

7. (6 points) The infrared spectrum of a compound with the formula C_{12}H_{16}O is shown below. Circle structures that are consistent with its IR spectrum.

![Infrared spectrum and structures](image)

C=C might be **excluded**.
8. (11 points) The $^1$H NMR spectrum of a compound with the formula $C_4H_8O$ is shown below. How many ($\pi$-bonds + rings) does $C_4H_8O$ have? 

Circle the part structures that are present in the molecule:

- CH$_2$-C
- CH$_3$-O
- CH$_3$-CH$_2$-C
- CH$_3$CH$_2$-O
- O=CH-
- H-O-

Extra Credit (3 points). The structure is:

Extra Credit (4 points. Do this if you have more time) CIRCLE any molecule whose most stable conformation has both an axial methyl group on the top face of the ring and an axial methyl group on the bottom face of the cyclohexane ring.
9. (20 points) Write the expected organic products of the following reactions.

(a) \[ \text{CH}_3 \text{CH}_2 \text{C} = \text{CH}_2 \xrightarrow{\text{H}_2\text{O}, \text{H}_2\text{SO}_4} \text{CH}_3 \text{CH} = \text{CH}_2 \xrightarrow{\text{H}_2\text{O}} \text{CH}_3 \text{CH} = \text{CH} \text{CH}_2 \text{CH}_3 \]

(b) \[ \text{CH}_3 \text{CH} = \text{CH} = \text{CH}_2 \xrightarrow{\text{H}_2, \text{Pt}} \text{C}_4\text{H}_8 \]

Show stereochemistry in 3D

(c) \[ \text{C}_6\text{H}_6 \xrightarrow{\text{Br}_2, \text{FeBr}_3} \text{C}_6\text{H}_5\text{Br} \]

(d) \[ \text{C}_7\text{H}_{12} \xrightarrow{\text{BH}_3} \xrightarrow{\text{H}_2\text{O}-\text{OH}, \text{NaOH}} \]

Name:_____________________________
10. (a) (8 points) Write an electron pushing mechanism for the reaction shown below. Show all intermediates and use curved arrows to show the movement of electrons that converts one intermediate to the next material.

(b) (8 points) Draw the reaction energy diagram for the above reaction. Clearly indicate \(\Delta H^\circ\) of reaction (heat of reaction) and \(\Delta H^*\) (activation energy) on the diagram. Put in energy levels for starting materials, intermediates, products, and transition states.

1____
2____
3____
4____
5____
6____
TOTAL_____

Circle the name of your discussion TA
Chris Paradise
Megan Jacobson
Maren Buck
Matt Windsor
Tamas Benkovics