I. Use VSEPR to determine the geometry of the following molecules or ions. Draw each structure showing the geometry of bonded atoms about the central atom. (12 points)

a.) PCl$_3$

b.) CO$_3^{2-}$

c.) CH$_2$CN

d.) NH$_2^-$

II. Draw another resonance form for each of the following molecules or ions. Show all bonded and nonbonded electron pairs and formal charges. (12 points)

a.) CH$_3$-C-NH$_2$  \( \leftrightarrow \)  CH$_3$-C=NH$_2$

b.) CH$_3$-C=C  \( \leftrightarrow \)  CH$_3$-C=CH

c.)

d.) CH$_3$-C=N-O

III. Draw structures for all of the secondary alcohols with the formula C$_6$H$_{13}$OH (constitutional isomers only). Label each isomer as chiral or achiral. (18 points)

**All isomers are chiral.**
IV. For each pair of compounds, circle the compound with the higher boiling point. (8 points)

a.) \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3 \)

\( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3 \)

c.) \( \text{CH}_2\text{Cl}_2 \)

\( \text{CHCl}_3 \)

b.) \( \text{CH}_3=\text{C}-\text{CH}_3 \)

\( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3 \)

d.) \( \text{C}=(\text{C})=\text{C} \)

\( \text{F} \)

V. Assign R or S configuration to the chiral carbons in each of the following molecules. (10 points)

a.)

\( \text{R} \)

\( \text{H}_3\text{C} \)

\( \text{C} \)

\( \text{C} \)

\( \text{OH} \)

\( \text{OH} \)

c.)

\( \text{R} \)

\( \text{NH}_2 \)

\( \text{C} \)

\( \text{C} \)

\( \text{OH} \)

\( \text{OH} \)

b.)

\( \text{S} \)

\( \text{Cl} \)

\( \text{R} \)

\( \text{Cl} \)

\( \text{H} \)

\( \text{OH} \)

\( \text{H} \)

d.)

\( \text{S} \)

\( \text{Cl} \)

\( \text{H} \)

\( \text{OH} \)

\( \text{H} \)

VI. Which of the following is a possible way to resolve a racemic mixture of lactic acid \( \text{CH}_3\text{CHCOH} \) into separate R and S enantiomers? (5 points)

a.) React the racemic mixture with an achiral amine and separate the products based on their different physical properties.

b.) React the racemic mixture with a racemic mixture of a chiral amine and separate the products based on their different physical properties.

c.) React the racemic mixture with one enantiomer of a chiral amine and separate the products based on their different physical properties.

d.) Directly separate the racemic mixture of lactic acid based on the different physical properties of R and S lactic acid.
VII. Sighting along the C2-C3 bond of 2,3-Dimethylbutane, draw Newman projections of the most stable and the least stable conformations. (10 points)

![Newman projections]

VIII. Circle the more stable isomer in each pair. (12 points)

a.) trans-1,2-Dimethylcyclohexane vs cis-1,2-Dimethylcyclohexane
b.) trans-1,3-Dimethylcyclohexane vs cis-1,3-Dimethylcyclohexane
c.) trans-1,3,5-Trimethylcyclohexane vs cis-1,3,5-Trimethylcyclohexane
d.) trans-1,4-Dimethylcyclohexane vs cis-1,4-Dimethylcyclohexane

IX. Clearly draw arrows and labels on the energy-reaction coordinate diagram shown below for each of the following. (8 points)

a.) Activation energy for the forward reaction ($\Delta G_f^+$)
b.) Activation energy for the reverse reaction ($\Delta G_f^-$)
c.) Free Energy of reaction ($\Delta G^0$)
d.) Transition State

![Energy-reaction coordinate diagram]

X. The reaction shown in problem IX is: (5 points)

a.) fast, exergonic
b.) fast, endergonic
c.) slow, exergonic
d.) slow, endergonic