This exam has eight (8) questions. Please check before beginning to make sure no questions are missing. All scratch work must be done on the attached blank pages, which will be collected. Please sign BOTH cover pages.
Periodic Table of the Elements

<table>
<thead>
<tr>
<th>Group</th>
<th>Period</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>O</th>
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</thead>
<tbody>
<tr>
<td>1.</td>
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<td>H</td>
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<td>H He</td>
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<td>2.</td>
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<td>Li Be</td>
<td>B C N O F Ne</td>
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<td>3.</td>
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<td>3</td>
<td>Na Mg</td>
<td>Al Si P S Cl Ar</td>
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<td>4.</td>
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<td>K Ca Se Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr</td>
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<td>5.</td>
<td>5</td>
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<td>Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe</td>
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<td>Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn</td>
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<td>Fr Ra Ac</td>
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<td>Fr Ra Ac</td>
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</tr>
</tbody>
</table>

Lanthanide Series

| Lanthanide | Series | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 |

Actinide Series

| Actinide | Series | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 | 101 | 102 | 103 |

ADVICE: A picture is worth a thousand words!
1. Boron trifluoride (BF₃) and ammonia (NH₃) undergo an acid-base reaction to give a new compound "X".

(a) Provide a detailed analysis of the structures of BF₃ and NH₃, including appropriate hybridization states of all valence orbitals, and approximate the relative bond angles. Indicate which species is the acid or base, and what kind of acid or base it is. (10 pts).

(b) Describe as completely as possible the structure of "X". Same criteria as above. (5 pts).

2. Acetic acid, shown below, can function as either an acid or base. What products would you expect upon reaction of acetic acid with H₂SO₄? Use resonance structures to justify your choice of products. 5 pts.

Protonation on C=O double bond allows resonance delocalization of positive charge (cf. problem 2.58).
3. Indicate the direction of the dipole moment, if any, for each of the following compounds. You must illustrate with accurate three dimensional drawings. (10 pts).

(a) CH₃⁻

(b) CH₃⁺

(c) CF₃CCl₃

(d) NH₂⁻

(e) CF₂Br₂

4. Draw a graph of potential energy versus rotation about the C₂-C₃ bond for 2-methylbutane, indicating the structures and relative energies (kJ) through a complete 360° cycle (use Newman projections). Point out the factors responsible for energy differences (i.e. van der Waal's repulsion or torsional strain). (10 pts).
5. For each pair of isomers given below circle the most stable isomer and provide a brief (4-5 words should suffice) explanation for your choice (you needn’t provide absolute energy differences, but use an accurate drawing to justify your choice). (20 pts).

a. cis-1,2-Dimethylcyclopropane vs trans-1,2-Dimethylcyclopropane

b. cis-1,2-Dimethylcyclobutane vs trans-1,2-Dimethylcyclobutane

c. cis-1,3-Dimethylcyclobutane vs trans-1,3-Dimethylcyclobutane

d. cis-1,3-Dimethylcyclohexane vs cis-1,2-Dimethylcyclohexane

e. trans-1,4-Dimethylcyclohexane vs trans-1,3-Dimethylcyclohexane
6. For each pair of compounds shown below, circle the one which will be the stronger acid. Explain your choice in 4-5 words. (10 pts).

(a) $\text{H}_3\text{O}^+$, $\text{H}_2\text{O}$  
(b) $\text{BF}_3$, $\text{NF}_3$  
(c) $\text{CH}_3\text{OH}$, $[\text{CCl}_3\text{OH}]^-$

H$_2$O more stable conj. base  
NF$_3$ not an acid (a Lewis base)  
CCl$_3$O$^-$ more stable conj. base

(d) $\text{CH}_3\text{OCH}_3$, $\text{CH}_3\text{OH}$  
(e) $\text{CF}_3^+$, $\text{BF}_3$

CH$_3$O more stable conj. base  
CF$_3^+$ more electron deficient

7. Draw a graph of energy vs structure for the chair, planar, half-chair, boat and twist-boat forms of cyclohexane. You needn’t provide exact energy differences, but you must clearly identify all factors that contribute to strain. This will require accurate drawings. (15 pts).
8. *Trans*-1,3-Di-tert-butylcyclohexane exists largely in a twist-boat conformation. Draw accurate representations of both the chair conformation and the likely twist-boat conformation, and then explain why the twist-boat form is favored (1-2 two sentences maximum). (5 pts).

In the chair conformation of *trans*-1,3-di-tert-butylcyclohexane one tert-butyl group must be axial, which is very unfavorable. The twist-boat conformation relieves this interaction.