This exam contains 17 questions on 7 numbered pages. Check now to make sure you have a complete exam. You have one hour and thirty minutes to complete the exam. Determine the best answer to the first 15 questions and enter these on the special answer sheet. Also, circle your responses in this exam booklet.

Show all of your work and provide complete answers to questions 16 and 17.

1-15 (30 pts.)
16 (15 pts.)
17 (15 pts.)

Total (60 pts)

Useful Information:

PERIODIC TABLE OF THE ELEMENTS

[Image of the periodic table]
1. Consider the carbon monoxide molecule pictured below. Note that the bond may be a single, double, or triple bond. What can best be said about the electrons involved in the bond?

![Box A Box B]

a) There is an equal chance of a bonding electron being in the area marked by either box. This is because carbon and oxygen are both in the same row of the periodic table.
b) There is an equal chance of a bonding electron being in the area marked by either box. This is because the molecule is linear.
c) A bonding electron is more likely to exist in the area marked by Box A because carbon needs more electrons to get to a noble gas electron configuration.
d) A bonding electron is more likely to exist in the area marked by Box B because the oxygen nucleus has a stronger attraction for electrons than does the carbon nucleus.
e) Because we never know where the electron is, we cannot say one way or the other where a bonding electron is more likely to be.

2. Which of the given statements best describes the following data?

First ionization energy for Na: 495 kJ/mol  
Electron affinity for Na: -50 kJ/mol
First ionization energy for Cl: 1255 kJ/mol  
Electron affinity for Cl: -349 kJ/mol
Heat of formation of NaCl: -525 kJ/mol

a) Energy is released when a sodium ion is formed from a sodium atom and when a chlorine ion is formed from a chlorine atom. This makes the formation of sodium chloride exothermic.
b) Energy is required to remove an electron from sodium, but more energy is released when chlorine takes an electron. This makes the formation of sodium chloride exothermic.
c) Energy is required to form both the sodium ion and the chloride ion, so the reaction to form sodium chloride is endothermic.
d) Energy is required to remove an electron from sodium and energy is released when chlorine takes an electron. Less energy is released than required for these two processes, though, so overall, the formation of sodium chloride is endothermic.
e) Energy is required to remove an electron from sodium, and energy is released when chlorine takes an electron. Less energy is released than required for these two processes, but overall the process is exothermic.

3. In which case is the bond polarity **incorrect**?

a) $\delta^+ \text{H}^- \text{F}^-$

b) $\delta^+ \text{S}^- \text{O}^-$

c) $\delta^+ \text{Mg}^+ \text{H}^-$

d) $\delta^+ \text{Cl}^- \text{I}^-$

e) $\delta^+ \text{Si}^- \text{S}^-$
4. Which of the following has a Lewis structure most like that of the carbonate ion?
   a) carbon dioxide
   b) the sulfate ion
   c) the nitrate ion
   d) ozone (O₃)
   e) nitrogen dioxide

5. How many of the following statements concerning resonance structures is/are correct?
   I. The concept of resonance is used because the Lewis structure model is incomplete in describing bonding in a molecule.
   II. For a species having three resonance structures, it is best to think of the species to exist as each of these structures one-third of the time.
   III. All charged molecules have resonance structures.
   IV. The octet rule must not be violated in writing resonance structures.
   a) 0   b) 1   c) 2   d) 3   e) 4

6. Which of the following best describes BF₃ and NF₃?
   a) They each have variable geometries and shapes due to potential resonance structures.
   b) They have the same geometry and different shapes.
   c) They have the same geometry and the same shape.
   d) They have different geometries and the same shape.
   e) They have different geometries and different shapes.

7. Determine the shape (molecular structure) of the following molecules/ions and the hybridization around the central atom

7. \([\text{XeF}_5]^+\)
   a) trigonal bipyramid, \(d^2sp^3\)
   b) see-saw, \(dsp^3\)
   c) trigonal bipyramid, \(dsp^3\)
   d) square pyramid, \(d^2sp^3\)
   e) None of these

8. \([\text{ICl}_2]^-\)
   a) bent, \(sp^3\)
   b) bent, \(dsp^3\)
   c) linear, \(dsp^3\)
   d) linear, \(sp^3\)
   e) None of these
9. Which of the following correctly labels the molecules as polar or non-polar?

<table>
<thead>
<tr>
<th></th>
<th>SO₂</th>
<th>BH₃</th>
<th>CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>polar</td>
<td>polar</td>
<td>polar</td>
</tr>
<tr>
<td>b)</td>
<td>non-polar</td>
<td>non-polar</td>
<td>non-polar</td>
</tr>
<tr>
<td>c)</td>
<td>polar</td>
<td>non-polar</td>
<td>polar</td>
</tr>
<tr>
<td>d)</td>
<td>polar</td>
<td>non-polar</td>
<td>non-polar</td>
</tr>
<tr>
<td>e)</td>
<td>non-polar</td>
<td>polar</td>
<td>polar</td>
</tr>
</tbody>
</table>

10. Identify the strongest intermolecular force for the given molecule

<table>
<thead>
<tr>
<th></th>
<th>C₂H₆</th>
<th>NH₃</th>
<th>CH₃OCH₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>LDF</td>
<td>H-bond</td>
<td>H-bond</td>
</tr>
<tr>
<td>b)</td>
<td>dipole-dipole</td>
<td>LDF</td>
<td>dipole-dipole</td>
</tr>
<tr>
<td>c)</td>
<td>H-bond</td>
<td>LDF</td>
<td>dipole-dipole</td>
</tr>
<tr>
<td>d)</td>
<td>LDF</td>
<td>dipole-dipole</td>
<td>dipole-dipole</td>
</tr>
<tr>
<td>e)</td>
<td>LDF</td>
<td>H-bond</td>
<td>dipole-dipole</td>
</tr>
</tbody>
</table>

11. Which of the following decreases as the strength of intermolecular forces increases?
   a) boiling point
   b) melting point
   c) vapor pressure
   d) surface tension
   e) All of the above increase with as the strength of intermolecular forces increases.

12. You mix 500.0 mL of 4.00 M Fe(NO₃)₃ with 500.0 mL 6.00 M KSCN. They react according to the following equation:

   \[ \text{Fe}^{3+}(aq) + \text{SCN}^-(aq) \rightleftharpoons \text{FeSCN}^{2+}(aq) \]

Since FeSCN²⁺ in solution appears red (and the reactants are colorless) you use a spectrophotometer and determine the concentration of FeSCN²⁺ at equilibrium to be 1.00 M. Determine the value of the equilibrium constant, \( K \), for the reaction above.

a) 0.0417  b) 0.0667  c) 0.100  d) 0.167  e) 0.500

13. Consider an acidic chromate-dichromate system at equilibrium in which the color is an orange-yellow. The reaction is represented by the equation

   \[ \text{Cr}_2\text{O}_7^{2-}(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{CrO}_4^{2-}(aq) + \text{H}^+(aq) \]

Which of the following best describes what happens if a strong base (which reacts with the \( \text{H}^+(aq) \)) is added to the system at equilibrium?

a) Both the color of the solution and the value for \( K \) remain the same.
b) The solution turns more yellow and the value for \( K \) increases.
c) The solution turns more orange and the value for \( K \) decreases.
d) The solution turns more orange and the value for \( K \) does not change.
e) The solution turns more yellow and the value for \( K \) does not change.
14. You mix two aqueous ionic solutions together and they do not react. To this you add (dropwise) a third aqueous ionic solution. At first a white solid forms. As you continue to add the third solution, a yellow solid begins to form. Which of the following can you say with confidence?

I. The solubility of the white solid is greater than the solubility of the yellow solid.
II. The solubility of the yellow solid is greater than the solubility of the white solid.
III. The $K_{sp}$ value for the white solid is greater than the $K_{sp}$ value for the yellow solid.
IV. The $K_{sp}$ value for the yellow solid is greater than the $K_{sp}$ value for the white solid.

a) I and III  
 b) II and IV  
 c) I only  
 d) II only  
 e) I and IV

15. Titrating 30.00 mL of a saturated calcium iodate solution requires 28.91 mL of a 0.092 M solution of Na$_2$S$_2$O$_3$ according to the equation. Calculate $K_{sp}$ for Ca(IO$_3$)$_2$.

$$\text{IO}_3^- + 6\text{S}_2\text{O}_3^{2-} + 6\text{H}^+ \rightarrow \text{I}^- + 3\text{S}_4\text{O}_6^{2-} + 3\text{H}_2\text{O}$$

Calculate the value of the solubility product constant ($K_{sp}$) for Ca(IO$_3$)$_2$.

a) $1.09 \times 10^{-4}$  
 b) $7.14 \times 10^{-8}$  
 c) $6.97 \times 10^{-4}$  
 b) $2.79 \times 10^{-3}$  
 e) $1.61 \times 10^{-6}$
16. For each of the following questions, **fully explain** your answer, using Lewis structures and VSEPR theory when appropriate.

a. The periodic table is an amazing achievement in human intellectual progress. Developed before atomic theory was widely accepted, it helps explain a variety of observations. For example, being in the same column, chlorine, bromine, and iodine are all diatomic in their standard states. It turns out, though that at room conditions, one is a gas, one is a liquid, and one is a solid. **Match** each element in its standard state with its phase and **explain** your answer. **[6 points]**

b. You and your lab partner accidentally and independently synthesize a compound with the formula XeCl₂F₂. Interestingly, your compound is a gas and your partner’s is a liquid, each at lab conditions. **Explain** how these compounds can have the same formulas yet exist in different phases at the same temperature and pressure. **[6 points]**
c. The formula of the reactant, N₂O, doesn’t tell us if the skeletal structure is N-O-N or N-N-O, nor does it tell us if there is a best Lewis structure. Your goal is to find the best Lewis structure for the compound, using formal charge as the primary basis. Define formal charge in your answer. Justify your answer completely. [8 pts.]
17. Gaseous hydrazine (N$_2$H$_4$) decomposes to nitrogen gas and hydrogen gas. At a certain temperature, K$_p$ = 3.50 x 10$^4$ for this reaction balanced in standard form. Pure gaseous hydrazine is placed in an otherwise empty rigid vessel and the pressure is noted. The reaction is allowed to reach equilibrium at this temperature and it is observed that the equilibrium pressure is double its initial value.

a. Determine the initial pressure of the hydrazine (in atm). Define any variables. [11 pts]

b. What percent (in terms of moles) of hydrazine decomposed to reach equilibrium? Explain your answer. [7 pts]

c. Determine the equilibrium pressure of hydrogen (in atm). [2 pts]