This exam contains 17 questions on 8 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  (45 pts.)

16  (23 pts.)

17  (22 pts.)

Total  (90 pts)

Useful Information:

**PERIODIC TABLE OF THE ELEMENTS**

![Periodic Table Image]
1. Which of the following statements are true?

I. As the difference in electronegativity between two atoms increases, the bond becomes more covalent in character.
II. Ionic bonding results from the sharing of valence electrons between two atoms.
III. The valence electrons in a polar bond are found nearer (on the average) to the more electronegative atom in the bond.
IV. It is possible for a molecule with polar bonds to have no overall dipole moment.

a) I, II  b) II, III  c) III, IV  d) All are true.  e) None are true.

2. Which of the following best completes the following sentence concerning trends on the periodic table? While there can be exceptions, in general

a) larger atoms have larger ionization energies, and smaller electronegativity values.
b) larger atoms have smaller ionization energies, and smaller electronegativity values.
c) larger atoms have smaller ionization energies, and larger electronegativity values.
d) larger atoms have larger ionization energies, and larger electronegativity values.

3. Which of the following statements (a-d) best explains why MgO forms an ionic compound with Mg$^{2+}$ and O$^{2-}$ ions?

a) Because the ionization energy of Mg is positive, the process is endothermic, so Mg$^+$ is not stable as an isolated ion.
b) The second ionization energy for an element is greater than the first ionization energy.
c) While the first electron affinity for O is exothermic, the second electron affinity is endothermic.
d) While the first electron affinity for O is endothermic, the second electron affinity is exothermic.

e) None of the above (a-d) adequately explains why MgO forms an ionic compound with Mg$^{2+}$ and O$^{2-}$ ions.

4, 5. Consider the following Lewis structure where E is an unknown element:

4. Which of following could be the identity of element E?

a) S  b) O  c) Br  d) Xe  e) Two of a-d could be the identity of E.

5. Which of the following correctly states a bond angle and shape around E?

a) 120°; trigonal planar
b) 120°; trigonal pyramidal
c) 90°; see-saw
d) 90°; T-shaped

e) 109°; tetrahedral
6. Complete the Lewis structure for the molecule given below by minimizing formal charge. Then, identify the hybridization around the carbon labeled 1 and the nitrogen labeled 2.

![Lewis structure](attachment:image.png)

C(1) \( \text{N}(2) \)

- a) \( sp^2 \) \( sp^2 \)
- b) \( sp^3 \) \( sp^3 \)
- c) \( sp^2 \) \( sp^3 \)
- d) \( sp^3 \) \( sp^2 \)
- e) None of the above correctly identify the hybridization around the carbon labeled 1 and the nitrogen labeled 2.

7. Complete the Lewis structure for the molecule given below by minimizing formal charge.

![Lewis structure](attachment:image.png)

How many \( \pi \) bonds are in the completed Lewis structure?

- a) 0
- b) 2
- c) 3
- d) 4
- e) 7

8. How many of the following molecules are non-polar?

- SF\(_4\)
- NH\(_3\)
- CH\(_4\)
- H\(_2\)O
- SO\(_2\)
- OCl\(_2\)
- OF\(_2\)
- CF\(_4\)
- XeCl\(_4\)

- a) 2
- b) 3
- c) 5
- d) 6
- e) 7

9. Which of the following pairs of molecules can be described with the same shape (molecular structure) although they have different geometries (electron-pair arrangements)?

- a) H\(_2\)O and SO\(_2\)
- b) OCl\(_2\) and OF\(_2\)
- c) NH\(_3\) and CH\(_4\)
- d) SF\(_4\) and CF\(_4\)
- e) At least two of the above (a-d) have the same shape but different geometries.
10. Hydrocarbons are molecules which consist only of hydrogen and carbon atoms. Some long-chained hydrocarbons are solids at room conditions. Which of the following is the best explanation for this?

a) Because of so many hydrogen atoms, there is a great deal of hydrogen bonding, which is a strong form of dipole-dipole interactions.

b) Hydrocarbons only exert weak London dispersion forces, but if they are long-chained, there are many of these interactions which add up.

c) Hydrocarbons exert ion-ion interactions, and these interactions are the strongest of the intermolecular forces. Thus, the molecules stick together with a great deal of force.

d) Hydrocarbons are polar, thus the intermolecular forces are dipole-dipole interactions. These interactions are quite strong and allow the molecules to stick together readily.

e) The statement is false – hydrocarbons cannot be solids at room conditions.

11. How many of the following statements must be true? Note: could be true means false.

I. CH₄ is expected to have a higher boiling point than CCl₄ due to the fact that CH₄ exhibits hydrogen bonding

II. Substances in which the molecules exhibit only London dispersion forces are gases at room conditions.

III. Molecules with polar bonds exhibit dipole-dipole interactions.

IV. The stronger the intermolecular forces exhibited by a substance, the higher the vapor pressure of the substance.

a) 0  b) 1  c) 2  d) 3  e) 4

12. For this question, use the balanced equation \( N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) \). You have three steel tanks each containing mixtures of \( N_2(g), H_2(g), \) and \( NH_3(g) \) at the same temperature. The pressures in the tanks are:

- **Tank 1**: \([N_2] = 2.00 \, M\) \([H_2] = 3.00 \, M\) \([NH_3] = 6.00 \, M\)
- **Tank 2**: \([N_2] = 2.00 \, M\) \([H_2] = 4.00 \, M\) \([NH_3] = 7.00 \, M\)
- **Tank 3**: \([N_2] = 3.00 \, M\) \([H_2] = 2.00 \, M\) \([NH_3] = 4.00 \, M\)

Two of the tanks have reached equilibrium. Which tank has not reached equilibrium, and which direction must the reaction proceed in order for that system to reach equilibrium?

a) Tank 1 has not reached equilibrium; the reaction in tank 1 must proceed to the left in order to reach equilibrium.

b) Tank 1 has not reached equilibrium; the reaction in tank 1 must proceed to the right in order to reach equilibrium.

c) Tank 2 has not reached equilibrium; the reaction in tank 2 must proceed to the left in order to reach equilibrium.

**d) Tank 2 has not reached equilibrium; the reaction in tank 2 must proceed to the right in order to reach equilibrium.**

e) Tank 3 has not reached equilibrium; the reaction in tank 3 must proceed to the left in order to reach equilibrium.
13. Consider the reaction as represented by the following equation.

\[ \text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g) \]

Initially, \([\text{N}_2] = 5.00\ M\) and \([\text{H}_2] = 4.00\ M\). At equilibrium, \([\text{H}_2] = 1.00\ M\) at a certain temperature. Determine the value for \(K\) for this reaction at this temperature.

a) 0.500  
b) 0.667  
c) 1.00  
d) 2.00  
e) 4.50

14. You have a system at equilibrium governed by the equation \(\text{PCl}_5(g) \rightleftharpoons \text{PCl}_3(g) + \text{Cl}_2(g)\), which is an exothermic reaction. How many of the following will shift equilibrium to the right?

I. Add more \(\text{PCl}_5(g)\) at constant volume and temperature.  
II. Decrease the pressure by changing the volume at constant temperature.  
III. Remove \(\text{Cl}_2(g)\) at constant volume and temperature.  
IV. Decrease the temperature at constant volume.

a) 0  
b) 1  
c) 2  
d) 3  
e) 4

15. The \(K_{sp}\) of \(\text{PbCl}_2\) is \(1.6 \times 10^{-5}\). Calculate the solubility of \(\text{PbCl}_2\) in a \(0.30\ M\ \text{NaCl}\) solution.

a) 5.3 x 10\(^{-5}\) M  
b) 2.7 x 10\(^{-5}\) M  
c) 1.6 x 10\(^{-5}\) M  
d) 4.4 x 10\(^{-5}\) M  
e) 1.8 x 10\(^{-4}\) M