1. My answers for this Chemistry 102 exam should be graded with the answer sheet associated with:
   a. Form A   b. Form B   c. Form C   d. Form D   e. Form E

2. Which of the statements (a-c) concerning the following reaction is/are true?

   \[ \text{CO}_2(\text{g}) + \text{H}_2(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g}) \quad K = 1.0 \times 10^{-8} \]

   a. Since \( K \ll 1 \), at equilibrium the rate of the reverse reaction will be greater than the rate of the forward reaction.
   b. Since \( K \ll 1 \), the reverse reaction is the dominant reaction, i.e., at equilibrium the reaction system will contain mostly reactants.
   c. The value of \( K \) at constant temperature depends on the amount of reactants and products that are mixed together initially.
   d. Two of the above statements (a-c) are true.
   e. All of the above statements (a-c) are true.

3. How many of the following five box diagrams correctly represent the ground state electron configuration for the element listed?

   a. 0 (None are correct.)   b. 1   c. 2   d. 4   e. 5 (All are correct.)
4. Which of the following (a-d) is/are the correct ground state electron configuration(s) for the elements/ions listed? Cd is element #48 and Te is element #52.

   a. Cr: \([\text{Ar}]4s^23d^4\)  
   b. Cu: \([\text{Ar}]4s^23d^9\)  
   c. Cd\(^{2+}\): \([\text{Kr}]5s^24d^8\)  
   d. Te\(^{2-}\): \([\text{Kr}]5s^24d^{10}5p^6\)  
   e. All of the above (a-d) are correct ground state electron configurations.

5. Consider the following reaction at 250°C:

\[
\text{N}_2(g) + 3 \text{H}_2(g) \rightleftharpoons 2 \text{NH}_3(g) \quad K = 0.278
\]

At equilibrium, \([\text{N}_2] = 0.50\) and \([\text{H}_2] = 1.3\). What is the equilibrium concentration of \(\text{NH}_3\)?

   a. 0.18  
   b. 0.25  
   c. 0.31  
   d. 0.43  
   e. 0.55

6. If the frequency of electromagnetic radiation is decreased by a factor of one-half, which of the following statements is false?

   a. The number of cycles passing a given point per unit time halves.  
   b. The velocity of the radiation halves.  
   c. The wavelength of electromagnetic radiation is doubled.  
   d. The energy of the electromagnetic radiation is halved.

7. Which of the following organic compounds has the lowest vapor pressure at -50°C?

   a. \(\text{CH}_4\)  
   b. \(\text{H}\frac{\text{H}}{\text{C}}\frac{\text{C}}{\text{H}}\frac{\text{H}}{\text{H}}\)  
   c. \(\text{H}\frac{\text{H}}{\text{C}}\frac{\text{O}}{\text{C}}\frac{\text{H}}{\text{H}}\)  
   d. \(\text{CH}_3\text{CH}_3\)  
   e. \(\text{H}\frac{\text{C}}{\text{C}}\frac{\text{H}}{\text{H}}\)
8. How many of the following five compounds have a trigonal pyramid shape?

<table>
<thead>
<tr>
<th>Compound</th>
<th>Shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH₃</td>
<td>Yes</td>
</tr>
<tr>
<td>NH₃</td>
<td>No</td>
</tr>
<tr>
<td>PF₃</td>
<td>Yes</td>
</tr>
<tr>
<td>ClO₃⁻</td>
<td>Yes</td>
</tr>
<tr>
<td>SO₃²⁻</td>
<td>Yes</td>
</tr>
</tbody>
</table>

a. 1   b. 2   c. 3   d. 4   e. 5 (All have a trigonal pyramid shape.)

9. A compound has a formula of QF₅ where Q is an unknown element. The compound has an even number of valence electrons and the central Q atom is d²sp³ hybridized. Which of the following elements could be Q?

a. Si   b. As   c. O   d. Br   e. Xe

10. Consider the following reaction:

\[ 2 \text{ NOCl(g)} \rightleftharpoons 2 \text{ NO(g)} + \text{ Cl}_2(g) \]

The reaction takes place at 35°C in a 2.0 L flask. At equilibrium, 4.0 mol NOCl, 0.10 mol NO and 0.050 mol Cl₂ are present. What is the value of \( K_P \) at 35°C?

a. \( 3.9 \times 10^{-4} \text{ M} \)   b. \( 1.6 \times 10^{-5} \text{ M} \)   c. \( 3.1 \times 10^{-5} \text{ M} \)

d. \( 7.9 \times 10^{-4} \text{ M} \)   e. \( 1.6 \times 10^{-2} \text{ M} \)

11. \( \text{N}_2\text{O}_5(g) \) decomposes into \( \text{O}_2(g) \) and \( \text{NO}_2(g) \). Which of the following is a correct equilibrium constant expression for this decomposition reaction?

a. \( \frac{[\text{O}_2][\text{NO}_2]^2}{[\text{N}_2\text{O}_5]} \)   b. \( \frac{[\text{N}_2\text{O}_5]}{[\text{O}_2][\text{NO}_2]^2} \)   c. \( \frac{[\text{O}_2][\text{NO}_2]}{[\text{N}_2\text{O}_5]} \)

d. \( \frac{[\text{N}_2\text{O}_5]}{[\text{O}_2][\text{NO}_2]} \)   e. \( \frac{[\text{O}_2][\text{NO}_2]^4}{[\text{N}_2\text{O}_5]^2} \)

12. How many of the following five compounds are polar?

<table>
<thead>
<tr>
<th>Compound</th>
<th>Polar</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF₄</td>
<td>Yes</td>
</tr>
<tr>
<td>SF₄</td>
<td>Yes</td>
</tr>
<tr>
<td>KrCl₂</td>
<td>No</td>
</tr>
<tr>
<td>PCl₅</td>
<td>Yes</td>
</tr>
<tr>
<td>SeF₂</td>
<td>Yes</td>
</tr>
</tbody>
</table>

a. 1   b. 2   c. 3   d. 4   e. 5
E in the Lewis structure below is a general symbol for some element. Consider this Lewis structure for the next two questions.

\[
\begin{array}{c}
\text{F} \\
\text{E} \quad \text{O} \\
\text{F} \\
\end{array}
\]

13. Which of the following elements could be E?
   a. C  
   b. Si  
   c. Ne  
   d. Kr  
   e. S

14. Which of the following statements is **false** concerning the EOF$_2^{2-}$ molecule represented above?
   a. The shape of EOF$_2^{2-}$ is T-shaped.
   b. The central E atom is dsp$^3$ hybridized.
   c. All the bond angles about the central E atom are 120°.
   d. It is impossible to draw a Lewis structure for EOF$_2^{2-}$ which satisfies the octet rule for all atoms in EOF$_2^{2-}$.

15. The properties of 4 consecutive elements in the periodic table (abbreviated Q, X, Y and Z) are listed below where IE = ionization energy and EN = electronegativity.

<table>
<thead>
<tr>
<th></th>
<th>Q</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>IE (kJ/mol)</td>
<td>786</td>
<td>1012</td>
<td>999</td>
<td>1256</td>
</tr>
<tr>
<td>Radius (pm)</td>
<td>118</td>
<td>110</td>
<td>103</td>
<td>100</td>
</tr>
<tr>
<td>EN</td>
<td>1.8</td>
<td>2.1</td>
<td>2.5</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Which of the following sets of elements best fits the properties of Q, X, Y, and Z (in this order) if the elements are from row three of the periodic table?
   a. Mg, Al, Si, P
   b. Al, Si, P, S
   c. Si, P, S, Cl
   d. P, S, Cl, Ar

16. Which list shows the elements in order of **increasing** number of unpaired electrons?
   a. Ge < Br < Os < Cd < V
   b. Cd < Br < Ge < V < Os
   c. V < Ge < Br < Cd < Os
   d. Cd < Ge < Br < Os < V
   e. Ge < V < Cd < Os < Br
17. Nitrogen is/are the central atoms(s) in each of the following compounds or ions. The central nitrogen atoms are all sp\(^2\) hybridized with one exception. Which compound or ion does not have a central nitrogen atom exhibiting sp\(^2\) hybridization?

a. N–N–N \((\text{N}_3^-)\)  
b. O–N–O \((\text{NO}_2^-)\)  
c. O–N–O \((\text{NO}_3^-)\)  
d. H–N–N–H \((\text{N}_2\text{H}_2)\)  
e. F–N–O \((\text{NOF})\)

18. Difluoromethane, CF\(_2\)H\(_2\), has been considered as a replacement for the chlorofluorocarbon freon, CF\(_2\)Cl\(_2\). The boiling point of CF\(_2\)H\(_2\) is \(-56^\circ\text{C}\) and the boiling point of CF\(_2\)Cl\(_2\) is \(-29^\circ\text{C}\). Which of the following statements concerning these two compounds is false? (Carbon is the central atom in both molecules.)

a. CF\(_2\)H\(_2\) exhibits hydrogen bonding intermolecular forces.  
b. Both compounds are gases at room temperature.  
c. CF\(_2\)Cl\(_2\) exhibits stronger London dispersion forces as compared to CF\(_2\)H\(_2\).  
d. Overall, CF\(_2\)Cl\(_2\) exhibits stronger intermolecular forces as compared to CF\(_2\)H\(_2\).

d
19. To be effective, a radio antenna must have a height of at least one-half the wavelength of the radio frequency being transmitted. Considering this, what is the minimum height you would expect for a WILL antenna if the station broadcasts at a frequency of 580 kHz? (1000 Hz = 1 kHz)

a. 258 meters  
b. 0.258 meters  
c. 103 meters  
d. 0.103 meters  
e. \(5.17 \times 10^8\) meters

d
20. The skeletal structure of N\(_2\)O\(_4\) is:

\[
\begin{array}{c}
\text{O} \\
\text{N} \\
\text{O} \\
\text{N} \\
\text{O} \\
\end{array}
\]

How many different resonance structures that obey the octet rule can be drawn for N\(_2\)O\(_4\)?

a. 2  
b. 4  
c. 5  
d. 6  
e. 8
21. The periodic table can be used to predict properties of undiscovered elements. Which of the following statements is **false** concerning the undiscovered elements 116-120?

   a. Element 116 is expected to have two unpaired electrons in the ground state.
   b. Element 117 is expected to have seven valence electrons.
   c. The ground state electron configuration for element 118 is expected to be \([\text{Rn}]8s^26f^{14}7d^{10}8p^6\).
   d. Element 119 (abbreviated with X) is expected to react with sulfur to form an ionic compound having the formula \(X_2S\).
   e. Element 120 is expected to form stable +2 charged cations when it forms ionic compounds.

22. An equilibrium mixture for the reaction:

   \[
   2 \text{NO}(g) + \text{O}_2(g) \rightleftharpoons 2 \text{NO}_2(g)
   \]

   contains 0.12 mol of \(\text{NO}_2\), 0.080 mol of \(\text{NO}\), and 0.64 mol of \(\text{O}_2\) in a 4.0 L bulb at a temperature, \(T\). What is the value of \(K\) for this reaction at this temperature?

   a. 88  
   b. 14  
   c. 9.4  
   d. 3.5  
   e. 2.3

23. In an investigation of the electronic emission spectrum of an unknown element having more than one electron, it was found that a photon having \(\lambda = 622\) nm is emitted as an electron drops from the 3s to the 2p energy level. From only this information, we can determine:

   a. the energy of the 2p energy level.
   b. the energy of the 3s energy level.
   c. the sum of the energies of the 2p and 3s energy levels.
   d. the difference in energy between the 2p and 3s energy levels.
   e. All of the above (a-d) can be determined.

24. Which of the following statements is **false** concerning the Schrödinger equation of the quantum mechanical model of the atom?

   a. Electrons are assumed to exhibit wave properties.
   b. Solutions to the Schrödinger equation give allowed energy levels for electrons in an atom.
   c. Solutions to the Schrödinger equation can be manipulated to give the probability of where an electron is, but can never be manipulated to give the exact motion of an electron.
   d. A \(2d_{z^2-y^2}\) orbital represents an allowed energy level as derived from the Schrödinger equation.
25. Which of the following statements is false?

a. Lone pairs of electrons can cause bond angles to be slightly smaller than predicted from VSEPR.
b. The central atom in a covalent molecule has the bonded atoms and lone pairs arranged around itself so to maximize electron-electron repulsions.
c. Covalent bonding results in the sharing of valence electrons between two atoms.
d. When the difference in electronegativity between two atoms is large, the bond most likely to form between the two atoms is an ionic bond.
e. The H–Cl bond is an example of a polar covalent bond where the valence electrons in the polar bond are found nearer (on the average) to the chlorine atom.

26. Place the following ions in order of increasing size (smallest to largest).

\[ \text{Sr}^{2+}, \text{Rb}^+, \Gamma, \text{Te}^{2-} \]

a. \( \Gamma < \text{Te}^{2-} < \text{Sr}^{2+} < \text{Rb}^+ \)

b. \( \Gamma < \text{Te}^{2-} < \text{Rb}^+ < \text{Sr}^{2+} \)

c. \( \text{Sr}^{2+} < \text{Rb}^+ < \Gamma < \text{Te}^{2-} \)

d. \( \text{Sr}^{2+} < \text{Rb}^+ < \text{Te}^{2-} < \Gamma \)

e. \( \text{Rb}^+ < \text{Sr}^{2+} < \text{Te}^{2-} < \Gamma \)

27. Can a photon of visible light (\( \lambda = 400 \) to 700 nm) have the appropriate energy to excite a hydrogen electron from the \( n = 1 \) energy state to the \( n = 6 \) energy state?

a. No, this requires higher energy electromagnetic radiation than the energy of visible light.

b. Yes, if \( \lambda = 486 \) nm.

c. Yes, if \( \lambda = 656 \) nm.

d. Yes, if \( \lambda = 526 \) nm.

e. No, this requires lower energy electromagnetic radiation than the energy of visible light.

28. Unknown elements X and Y are in the same family (group) in the periodic table. Element Y has more protons in the nucleus as compared to element X. Which of the following statements concerning elements X and Y is most likely false?

a. Elements X and Y should have the same number of valence electrons.

b. Element Y should have a larger atomic number than element X.

c. Element X should have a larger electronegativity value than element Y.

b. Element X should have a smaller radius than element Y.

e. Element Y should have a larger ionization energy than element X.
Vitamin B₆ is an organic compound whose deficiency in the human body can cause apathy, irritability, and an increase susceptibility to infections. Below is an incomplete Lewis structure for vitamin B₆. Using the guidelines covered in class regarding Lewis structures for organic compounds, complete the Lewis structure and answer the next two questions. Ignore any possible resonance structures.

29. How many of the C and N atoms are sp² hybridized?
   a. 1    b. 3    c. 4    d. 6    e. 7

30. What are the approximate bond angles about the oxygen atom labeled 1 and the carbon atom labeled 2, respectively?
   a. 109°; 120° b. 120°; 90° c. 180°; 120° d. 180°; 180° e. 109°; 90°

31. Consider the following bond lengths: C–O 143 pm; C=O 123 pm; C≡O 109 pm. Which of the following statements (a-d) is true concerning the bonding in CO₃²⁻?
   a. One of the carbon-oxygen bonds in CO₃²⁻ has a bond length of 123 pm and the other two carbon-oxygen bonds have a bond length of 143 pm.
   b. The length of the three carbon-oxygen bonds in CO₃²⁻ all should be equal with a bond length somewhere between 109 pm and 123 pm.
   c. The length of the three carbon-oxygen bonds in CO₃²⁻ all should be equal with a bond length somewhere between 123 pm and 143 pm.
   d. The delocalized π bonding system in CO₃²⁻ is formed from overlap of sp² hybrid orbitals on each atom in CO₃²⁻.
   e. None of the above statements (a-d) are true.