Multiple choice (3 points each).

1. The Oxidation number of the N in ammonium, the N in nitrate and the C in methane change by how much, respectively, in the following reaction:

\[ 2\text{NH}_4\text{NO}_3(s) + \text{CH}_4(g) \rightarrow \text{N}_2(g) + \text{CO}_2(g) + 6\text{H}_2\text{O}(l) \]

a. 0, 0, 0    c. -4, 4, 2    e. 2, -4, 2    g. -4, +4, +8    i. +4, -8
b. 2, 2, -2    d. +4, -6, +8    f. -4, +6, +8    h. none of the above    j. Cannot be determined

2. Which of the following represent a decrease in \( \Delta E \):

a. The temperature of a gas decreases (all else constant).
b. The \( \Delta E \) of a truck when it pushes a boulder up a hill.
c. The \( \Delta E \) of the boulder above.
d. The \( \Delta H \) of a constant pressure, constant volume process is -42 J.
e. a and c.
f. a, b, d
g. all of the above
h. none of the above

3. Which of the following are State Functions:

a. \( H \)    c. \( \Delta E \)    e. heat    g. a, b, c    i. b, c    j. none of the above
b. \( \Delta H \)    d. work    f. a, b    h. all of the above

4. Which of the following reactions can directly do the most work on the surroundings:

a. \( \text{H}_2(g) + \text{O}_2(g) \rightarrow \text{H}_2\text{O}(l) \)
b. \( \text{HCl(aq)} + \text{NaOH(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O} \)
c. \( 2\text{C}_6\text{H}_6\text{O}_6(s) + 12\text{O}_2(g) \rightarrow 6\text{H}_2\text{O}(l) + 12\text{CO}_2(g) \)
d. \( \text{Na(CO}_3)_2\text{(aq)} +\text{HCl(aq)} \rightarrow 2\text{CO}_2(g) + \text{2H}_2\text{O(l)} \)
e. \( \text{P}_4 + 5\text{O}_2(g) \rightarrow 2\text{P}_2\text{O}_5(s) \)
5. How many of the following substances have standard heats of formation equal to zero?

<table>
<thead>
<tr>
<th>Substance</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C(s)</td>
<td>O(g)</td>
</tr>
<tr>
<td>P(_2)O(_5) (s)</td>
<td>Br(_2) (l)</td>
</tr>
</tbody>
</table>

a. 0   c. 2   e. 4   g. 6   i. 8
b. 1   d. 3   f. 5   h. 7

6. A speaker is vibrating at a regular frequency of 150 Hz. What is the wavelength of the waves produced (the speed of sound is 344 m/s).

a. 334 m   b. 2.29 m   c. 1.8 \(\times 10^4\) m   d. 2.4 J   e. 82 cm
f. none of the above

7. The frequency of orange light is approximately \(5 \times 10^{14}\) s\(^{-1}\) and the frequency of violet light is approximately \(7.5 \times 10^{14}\) s\(^{-1}\). How many photons of orange light have the same total energy as 2 photons of violet light?

a. 1   c. 2   e. 3   g. 4   i. 5
b. 1.5   d. 2.5   f. 3.5   h. 4.5   j. 5.0

8. A piece of metal is heated in a forge. Which of the following statements best describes what happens.

a. Light of gradually higher frequency is given off because of the increased kinetic energy of the atoms because this kinetic energy is quantized.
b. Light of gradually lower frequency is given off because of the kinetic energy of the atoms because this kinetic energy is quantized.
c. Light of gradually smaller wavelength is given off because the kinetic energy of the electrons is quantized.
d. Light of gradually longer wavelength is given off because the kinetic energy of the electrons is quantized.
e. Light of gradually smaller wavelength is given off because the electrons in lower energy levels are leaving the atom and being replaced by other electrons.
f. a, c and e.
g. b and d.
h. All of the above.

9. What letters correspond to the following values of the secondary quantum number \(l\)? Choose the row where all of the choices are correct.

\[
\begin{array}{cccc}
  l = 2 & l = 0 & l = 3 & l = 1 \\
  a. & s & p & d & f \\
  b. & s & f & d & p \\
  c. & p & s & f & d \\
\end{array}
\]
10. According to the periodic table, which orbital is filled after the 3d orbital?
   a. 4s  c. 4p  e. 4d  g. 3p
   b. 3f  d. 4f  f. 5s  h. 3s

11. If the allowed quantum numbers for \( m \) were \(-2l, -2l+1, ..., 2l-1, 2l\), how many elements would be in the second row?
   a. 8  c. 10  e. 12  g. 14  i. 16
   b. 9  d. 11  f. 13  h. 15  j. none of the above

12. Which of the following types of electromagnetic radiation is highest in energy?
   a. microwaves  c. infrared  e. visible  g. radio
   b. ultraviolet  d. X-rays  f. laser  h. none of the above

13. How many unpaired electrons are in an Arsenic (As) atom?
   a. 0  c. 1  e. 2  g. 3
   b. 4  d. 5  f. 6  h. none of the above

14. There are _______ orbitals in the complete fourth shell.
   a. 25  c. 4  e. 14  g. 16
   b. 32  d. 8  f. 12  h. None of the above

15. The _______ quantum number is most responsible for defining the shape of an orbital.
   a. spin  c. azimuthal  e. \( \Psi \)  d. magnetic
   b. n  d. \( m_s \)

16. \([Ar]4s^23d^{10}4p^1\) is the electron configuration for a(n) __________ atom.
   a. As  c. V  e. P  g. Ga
   b. Sb  d. Sn  f. Ge  h. None of the above

17. Predict the atomic number of the next Noble gas (below Rn).
   a. 126  c. 11  e. 106  g. None of the above
   b. 96  d. 118  f. 136

18. The ground state electron configuration for a Cd atom is:
   a. \([Ar]4s^24d^9\)  c. \([Kr]5s^23d^9\)  e. \([Xe]5s^25d^{10}\)
   b. \([Kr]5s^23d^{10}\)  d. \([Kr]5s^24d^{10}\)  f. \([Xe]5s^15d^{11}\)
   g. None of the above
Problems, show work ON THIS SHEET. Use additional paper if necessary
(8 points each)

19. The bombardier beetle uses an explosive discharge as a defensive measure. The
chemical reaction involved is the oxidation of hydroquinone by hydrogen peroxide to
produce quinone and water.

\[
C_6H_4(OH)_2(aq) + H_2O_2(aq) \rightarrow C_6H_4O_2(aq) + 2 H_2O(l)
\]

Calculate \( \Delta H \) for the above reaction from the following data.
\[
\begin{align*}
C_6H_4(OH)_2(aq) &\rightarrow C_6H_4O_2(aq) + H_2(g) \quad \Delta H = +177.4 \text{ kJ} \\
H_2(g) + O_2(g) &\rightarrow H_2O_2(aq) \quad \Delta H = -191.2 \text{ kJ} \\
H_2O(g) + 1/2 O_2(g) &\rightarrow H_2O(g) \quad \Delta H = -241.8 \text{ kJ} \\
H_2O(g) &\rightarrow H_2O(l) \quad \Delta H = -43.8 \text{ kJ}
\end{align*}
\]

20. Under constant-volume conditions, the heat of combustion of glucose (C_6H_12O_6) is
15.57 kJ/g. A 9.4500 g sample of glucose is burned in a bomb calorimeter. The
temperature increased from 20.7 °C to 28.2 °C.

a. What is the total heat capacity of the calorimeter?
b. If the size of the glucose sample had been exactly twice as large, what would the final
temperature of the calorimeter have been?
21. Consider the following reaction:
   \[ \text{CH}_3\text{OH}(g) \rightarrow \text{CO}(g) + 2\text{H}_2(g) \quad \Delta H = 90.7 \text{ kJ} \]
   a. Is heat absorbed or evolved in the course of this reaction?
   b. Calculate the amount of heat transferred when 62 g of CH\(_3\)OH(g) is decomposed by this reaction at constant pressure.
   c. For a given sample of CH\(_3\)OH, the enthalpy change on reaction is 36.7 kJ. How many grams of hydrogen gas are produced?

22. How many grams of methane (CH\(_4\)(g)) must be combusted to heat 2.4 kg of water 25 °C to 85 °C, assuming a standard combustion reaction?
   \[ \text{CH}_4(g) + 2\text{O}_2(g) \rightarrow 2\text{H}_2\text{O}(g) + \text{CO}_2(g) \]
   \[ \Delta H_{\text{form}} \]  
   \[ -74.8 \quad 0 \quad -241.8 \quad -393.5 \]
23. Light of 300 nm wavelength is required to eject an electron from a metal surface. What will the kinetic energy of the electron be if it absorbs a photon with a wavelength of 200 nm?

24. Draw a figure that represents the following orbitals. Show any nodes or nodal planes:
   
   a. the 2s orbital
   b. The 3p orbitals
   c. The five 3d orbitals.