This exam contains 22 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 20 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 21 and 22. The answers must be kept within the spaces provided.

1-20 (40 pts.) _________
21 (18 pts.) _________
22 (22 pts.) _________
Total (80 pts) _________

Useful Information:
Always assume ideal behavior for gases (unless explicitly told otherwise).

PV = nRT  \{R = 0.08206 \text{Latm/molK}\}

Root mean square velocity = \sqrt{\frac{3RT}{M}}

\lambda = s \times m \times \Delta T

K = ^\circ \text{C} + 273

E= \frac{hc}{\lambda} \quad \Delta E = -2.178 \times 10^{-18} \text{J} \left[ \frac{1}{n_f^2} - \frac{1}{n_i^2} \right]

c = 2.998 \times 10^8 \text{m/s} \quad 1 \text{nm} = 10^{-9} \text{m} \quad h = 6.62608 \times 10^{-34} \text{Js}
1. A 2.25 g sample of scandium (Sc) metal is reacted with excess hydrochloric acid to produce 2.41 L of hydrogen gas at 100°C and 0.950 atm. Determine the formula of the “scandium chloride” produced in the reaction.

a) ScCl   b) ScCl₂  c) ScCl₃  d) Sc₂Cl₃  e) ScCl₄

2. Consider three identical steel tanks each filled with 40.0 g of argon (Ar) gas at 25.0°C. The pressure in each of the tanks is changed in different ways as described below:

- An additional 40.0 g of argon gas is added to tank #1 at constant temperature.
- A 25.0-g sample of neon (Ne) gas is added to tank #2 at constant temperature.
- The temperature of tank #3 is increased to 50.0°C.

Which of the following statements is true after the pressure is changed in each of the tanks?

a) The pressure in tank #1 is the highest.
b) The pressure in tank #2 is the highest.
c) The pressure in tank #3 is the highest.
d) The pressure in each of the tanks is the same after the changes.
e) The pressure in two of the tanks is equally high.

3. A sample of gas at 38°C occupies a volume of 2.97 L and exerts a pressure of 3.14 atm. The gas is heated to 118°C and the volume is decreased to 1.04 L. Determine the new pressure exerted by the gas.

a) 0.875 atm  b) 2.89 atm  c) 7.13 atm  d) 11.3 atm  e) 92.3 atm

4. How many of the following statements are true?

- A gas particle that is behaving ideally has no mass.
- The observed pressure of a real gas is higher than the expected ideal pressure.
- The gas particles of a theoretical ideal gas would not collide with each other.
- Carbon dioxide will behave more ideally than helium at the same conditions of pressure and temperature.
- At the same conditions of pressure and temperature, hydrogen molecules will collide with the walls of their container about twice as much as helium atoms.

a) 1  b) 2  c) 3  d) 4  e) 5

5. At 25°C, the following enthalpies of reaction are known:

\[
\begin{align*}
2\text{ClF(g)} + \text{O}_2(g) &\rightarrow \text{Cl}_2\text{O(g)} + \text{F}_2\text{O(g)} \quad \Delta H = 167.4 \\
2\text{ClF}_3(g) + 2\text{O}_2(g) &\rightarrow \text{Cl}_2\text{O(g)} + 3\text{F}_2\text{O(g)} \quad \Delta H = 341.4 \\
2\text{F}_2(g) + \text{O}_2(g) &\rightarrow 2\text{F}_2\text{O(g)} \quad \Delta H = -43.4 
\end{align*}
\]

At the same temperature, calculate \(\Delta H\) for the reaction \(\text{ClF(g)} + \text{F}_2(g) \rightarrow \text{ClF}_3(g)\).

a) 217.4 kJ  b) −217.4 kJ  c) 465.4 kJ  d) 108.7 kJ  e) −108.7 kJ
6. Consider dropping a piece of sodium metal into liquid water. The products are aqueous sodium hydroxide and hydrogen gas. Determine $\Delta H$ for this reaction when 1.00 mole of hydrogen gas is produced, given the following data:

$$
\Delta H_f^°[\text{H}_2\text{O}(l)] = -286\text{kJ/mol} \quad \Delta H_f^°[\text{NaOH}(aq)] = -470 \text{kJ/mol}
$$

a) 368 kJ  
   b) −368 kJ  
   c) 184 kJ  
   d) −184 kJ  
   e) −1512 kJ

7. A 25.0 g sample of copper (specific heat capacity = 0.385 J/g°C) is placed in a boiling water bath until the temperature of the metal is 100.0°C. The metal is quickly transferred to 100.0 g of water at 25.0°C in a calorimeter (specific heat capacity of water = 4.18 J/g°C). Determine the final temperature of the water in the calorimeter.

a) 22.2°C  
   b) 23.3°C  
   c) 25.9°C  
   d) 26.7°C  
   e) 27.8°C

8. Which of the following processes (a-d) is/are endothermic?

a) A snowman melts.  
b) Steam condenses on a mirror.  
c) Hydrogen gas and oxygen gas react to form water.  
d) A match burns.  
e) At least two of the above process (a-d) are endothermic.

9. How many of the following statements are true?

- Removing an electron from $X^+$ always requires more energy than removing an electron from $X$.
- Removing an electron from a Group I element (Li, Na, K, etc.) is exothermic because these become more stable by losing an electron.
- For an isoelectronic series (one in which all atoms/ions have an equal number of electrons), the one with the greatest number of protons has the smallest radius.
- The probability of finding the electron in the hydrogen atom is equally spread throughout what we call the s orbital.
- The electron affinity value for an element is the same magnitude but opposite in sign as the ionization energy for that element.

a) 1  
b) 2  
c) 3  
d) 4  
e) 5

10. Determine the number of electrons in an atom that can have the following quantum numbers and choose the set with the greatest number of electrons

a) $n = 5, l = 5$  
b) $n = 3, l = 2, m_l = 1$  
c) $n = 2, l = 1$  
d) $n = 2, l = 0$  
e) $n = 4, l = 3, m_l = 3, m_2 = \frac{1}{2}$
11. Which of the following best explains the ratio of $\frac{2^{nd} \text{ionization energy}}{1^{st} \text{ionization energy}}$ for Ar and Cl?

a) The ratio for Ar is much greater than that for Cl because Ar has more protons than Cl.
b) The ratio for Ar is much greater than that for Cl because Ar has a filled outer shell of electrons.
c) The ratio for Ar is much less than that for Cl because the $1^{st}$ ionization energy for Ar is greater than the $1^{st}$ ionization energy of Cl.
d) The ratio for Ar is much less than that for Cl because Ar has a filled outer shell of electrons.
e) The ratio for Ar is about the same as that for Cl since all electrons are removed from the same type of orbitals in the same energy level.

12. You are studying for Chemistry 102 when a friend says “Ionization energies generally increase across a row on the periodic table. However, there can be an exception between elements in column 5A and elements in column 6A. This has to do with electron-electron repulsions in doubly filled orbitals.” Which of the following statements best describes your friend’s remark?

a) It is completely wrong.
b) It is correct.
c) Ionization energies do increase across a row, but there are no exceptions.
d) Ionization energies do increase across a row, and there are exceptions, but not between columns 5A and 6A.
e) Ionization energies do increase across a row, and there are exceptions between columns 5A and 6A, but not for the reason that is stated.

13. What information do we get from this plot of radial probability distribution for the hydrogen atom?

![Graph of Radial Probability Distribution for Hydrogen Atom]

a) There is a most probable distance of the electron from the nucleus in a hydrogen atom.
b) Bohr’s model is the correct way to think about the hydrogen atom.
c) An electron has maximum probability of being located right at the nucleus.
d) There is only one orbital possible in the hydrogen atom.
e) Energy levels are quantized.

14. Calculate the wavelength of light emitted when an electron in the hydrogen atom goes from the $n = 3$ to the $n = 2$ state.

a) 314.1 nm       b) 417.5 nm       c) 547.2 nm       d) 656.7 nm       e) 714.2 nm
15. Use the data below from the text to determine the change in energy expected for the following process:

\[ \text{Mg}(g) + 2\text{F}(g) \rightarrow \text{Mg}^{2+}(g) + 2\text{F}^-(g) \]

<table>
<thead>
<tr>
<th>Atom</th>
<th>Electron Affinity (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>−327.8</td>
</tr>
<tr>
<td>Cl</td>
<td>−348.7</td>
</tr>
<tr>
<td>Br</td>
<td>−324.5</td>
</tr>
<tr>
<td>I</td>
<td>−295.2</td>
</tr>
</tbody>
</table>

a) 789 kJ  b) 1117 kJ  c) 1524 kJ  d) 1852 kJ  e) 2509 kJ

16. A friend states “I am thinking of an atom that, in its ground state, has two unpaired electrons in the p orbitals.” Using the periodic table given to you for the exam, how many elements could this describe?

a) 1  b) 2  c) 5  d) 10  e) 30

17. An excited state electron configuration for the ion \( X^+ \) is \( 1s^22s^22p^43s^1 \). What is the identity of the element \( X \)?

a) O  b) F  c) Ne  d) Na  e) Mg

18. Choose the atom/ion with the largest radius from both groups:

I. P vs. Cl  II. F\(^-\) vs. Ne

a) P, F\(^-\)  b) P, Ne  c) Cl, F\(^-\)  d) Cl, Ne

19. Which of the following lists the atoms from largest to smallest atomic radius?

a) Na, Be, Mg, B, N  b) Mg, Na, N, B, Be  c) N, B, Be, Mg, Na  d) Be, B, N, Na, Mg  e) Na, Mg, Be, B, N

20. Which of the following pairs of atoms is expected to have the most similar first ionization energies?

a) Na and Mg  b) Si and P  c) B and F  d) F and Cl  e) Fe and Co