Part I. Circle your answers for multiple choice questions

1. Which of the following is/are true regarding bomb calorimetry and constant pressure calorimetry?
   (Circle all that apply. There may be more than one answer)
   A) bomb calorimetry and constant pressure calorimetry are the same technique
   B) in both techniques, the volume remains constant
   C) in both techniques, work is zero
   D) in both techniques, a compound is always burned in excess oxygen
   E) in both techniques, heat flows are measured through temperature changes

2. Which of the following statements is false regarding electromagnetic radiation?
   A) electromagnetic radiation is a form of energy transmission
   B) visible light is a type of electromagnetic radiation
   C) wavelength and frequency are inversely proportional
   D) electromagnetic radiation can only exist at certain, discrete wavelengths
   E) for electromagnetic radiation, higher frequency corresponds to higher energy

3. The heat of formation of lead (II) carbonate is \(-699\) kJ/mol. Which equation below best represents this process?
   A) \( \text{Pb} + \text{C} + \text{O}_2 \rightarrow \text{PbCO}_3 \)
   B) \( \text{Pb} + \frac{3}{2} \text{O}_2 \rightarrow \text{PbCO}_3 \)
   C) \( 2 \text{Pb} + 2 \text{C} + 3 \text{O}_2 \rightarrow 2 \text{PbCO}_3 \)
   D) \( \text{PbCO}_3 \rightarrow \text{Pb} + \text{C} + \frac{3}{2} \text{O}_2 \)
   E) \( 2 \text{PbCO}_3 \rightarrow 2 \text{Pb} + 2 \text{C} + 3 \text{O}_2 \)

4. Which of the following properties would not influence the conductivity of a solution?
   A) The concentration of ions present
   B) The number of ions present
   C) The molar conductivity of the ions present
   D) The size of the container
   E) All of the above influence solution conductivity

5. Electrons in helium atoms transition from the 5th to the 2nd energy shell. If you observe the electromagnetic radiation that results, what would you observe?
   A) An emission spectrum with one line
   B) A continuous spectrum
   C) An absorption spectrum with multiple “dark” lines
   D) An absorption spectrum with a single “dark” line
   E) White light

6. Given the following activity series, list all of the ions (from those listed) that can be reduced by Zn metal.
   \[
   \begin{align*}
   \text{Al} & \rightarrow \text{Al}^{3+} + 3 \text{e}^- \\
   \text{Mn} & \rightarrow \text{Mn}^{2+} + 2 \text{e}^- \\
   \text{Zn} & \rightarrow \text{Zn}^{2+} + 2 \text{e}^- \\
   \text{Cr} & \rightarrow \text{Cr}^{3+} + 3 \text{e}^- \\
   \text{Fe} & \rightarrow \text{Fe}^{2+} + 2 \text{e}^-
   \end{align*}
   \]
   Increasing ease of oxidation
   Ions able to be reduced: \( \text{Cr}^{3+}, \text{Fe}^{2+} \)
7. Consider the following four cases:
   i. A chemical process in which heat is absorbed
   ii. A change in which \( q = 30 \) J and \( w = 44 \) J
   iii. A process in which a system does work on its surroundings with no change in \( q \)
   iv. A process in which work is done on a system and an equal amount of heat is withdrawn

In how many of these cases does the internal energy of the system decrease?

A) 0  
B) 1  
C) 2  
D) 3  
E) 4

8. The oxidation state of the Cl atom in KClO₅ is \( +5 \)

Part II. Show All Your Work!

9. What is the wavelength of light that has a frequency of 107.8 MHz?

\[
\lambda = \frac{c}{f} = \frac{2.998 \times 10^8 \text{ m/s}}{107.8 \times 10^6 \text{ /s}} = 0.02781 \text{ m} = 2.781 \text{ m}
\]

10. If 50.0 mL of a 0.350 M sulfuric acid solution (H₂SO₄) is needed to neutralize a solution of KOH, how many moles of KOH must be present in the solution?

\[
\begin{align*}
2 \text{ KOH} + \text{H₂SO₄} & \rightarrow 2 \text{ H₂O} \quad \text{K₂SO₄} \\
\frac{350 \text{ mol} \text{ H₂SO₄}}{1 \text{ L}} & \times \frac{2 \text{ mol} \text{ KOH}}{1 \text{ mol} \text{ H₂SO₄}} = 0.0350 \text{ mol KOH}
\end{align*}
\]

11. A sodium lamp emits light at 589 nm (yellow light). If you place a sodium lamp above a bowl that contains 350. mL of water, how many photons must be absorbed to raise the temperature of the water by 20 °C? Assume no energy from the contents of the bowl is lost to the surroundings, and the density of water is 1.00 g/mL. The heat capacity of water is 4.184 J/g °C.

\[
E_{\text{photon}} = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} \text{ J s}) (3.0 \times 10^8 \text{ m/s})}{589 \times 10^{-9} \text{ m}} = 3.375 \times 10^{-19} \text{ J/photons}
\]

\[
q = mcΔT = (350 \text{ g}) (4.184 \text{ J/g °C}) (20° \text{ C}) = 29288 J
\]

\[
\frac{29288 J}{3.375 \times 10^{-19} \text{ J/photons}} = 8.68 \times 10^{22} \text{ photons} \quad (0.124 \text{ mol photons})
\]
12. Thiosulfate ion ($S_2O_3^{2-}$) is important for the treatment of excess chlorine used industrially for the bleaching of fibers. Balance this oxidation-reduction reaction (shown below) that occurs in acid solution:

$$S_2O_3^{2-} (aq) + Cl_2 (aq) \rightarrow HSO_4^- (aq) + Cl^- (aq)$$

$$5H_2O + S_2O_3^{2-} \rightarrow 2HSO_4^- + 8H^+ + 8e^-$$

$$4\left[2e^- + Cl_2 \rightarrow 2Cl^-\right]$$

$$S_2O_3^{2-} + 4Cl_2 + 5H_2O \rightarrow 2HSO_4^- + 8Cl^- + 8H^+$$

13. When a 16.46 g sample of potassium chlorate ($KClO_3$) is dissolved in 200 g of water in a coffee-cup calorimeter, the temperature falls from 25.0 °C to 18.4 °C. Assume an isolated system where the heat capacity of the solution is 4.184 J/g °C. What is the enthalpy change ($\Delta H$, in kJ/mol) for the solution process of $KClO_3$ dissolving in water (shown below in equation form)?

$$KClO_3(s) \rightarrow KClO_3(aq)$$

$$mol \ KClO_3 = \frac{16.46 \ g}{122.6 \ g/mol} = 0.134 \ mol$$

$$n \ \Delta H = -m \ C \ \Delta T$$

$$\Delta H = - (16.46 \times 4.184 \times (18.4 - 25.0))$$

$$\Delta H = 45 \ kJ/mol$$
14. 0.488 g of solid Mg(OH)₂ are dissolved in 25.0 mL of a 3.0 M HNO₃ solution. After the reaction is complete, the solution remains acidic.

a) Write a balanced equation for the reaction that has occurred.

\[ \text{Mg(OH)₂} + 2 \text{HNO₃} \rightarrow 2 \text{H₂O} + \text{Mg(NO₃)₂} \]

b) If you assume the volume of the solution remains constant at 25.0 mL after the reaction is complete, identify the following concentrations: Molar masses that may prove useful: Mg(OH)₂ = 58.309 g/mol, HNO₃ = 63.0128 g/mol, H₂O = 18.0153 g/mol

The final concentration of NO₃⁻: 3.0 M

The final concentration of Mg²⁺: 0.34 M (or 0.335 M)

The final concentration of H⁺: 2.3 M

\[
\frac{0.488 \text{ g Mg(OH)₂}}{58.309 \text{ g/mol}} = 8.37 \times 10^{-3} \text{ mol Mg(OH)₂} = 8.37 \times 10^{-3} \text{ mol Mg}^{2+} = 0.335 \text{ M}
\]

\[
\frac{3.0 \text{ mol HNO₃}}{1.00 \text{ L}} \times 0.025 \text{ L} = 0.075 \text{ mol HNO₃ = 0.075 mol H⁺ (Start)}
\]

\[
0.075 - 0.01674 = 0.05826 = 2.33 \text{ M}
\]