Part I. Short Answer (5 points each) (Answer 7 of 8) Cross out the question that you skip.

1) Calculate the value of $\Delta E$ in joules for a system that loses 73 J of heat and has 150 J of work performed on it by the surroundings.

$$q = -73 \text{ J} \quad w = +150 \text{ J}$$

$$\Delta E = q + w = -73 \text{ J} + 150 \text{ J} = 77 \text{ J}$$

2) Given the following conditions, indicate how the internal energy of the system change. Answer either Increase, Decrease, or Not Enough Data.

a) The system loses heat and does work on the surroundings. **Decrease**

b) The system gains heat and does work on the surroundings. **Not Enough Data**

c) The system loses heat and has work done on it by the surroundings. **Not Enough Data**

d) The system gains heat and has work done on it by the surroundings. **Increase**

e) The system loses heat and there is no work done on it by the surroundings. **Decrease**

3) What is the oxidation number of each METAL in the following:

A) $\text{MnO}_4^-$

$$\text{Mn}^{\text{+7}}$$

$$x + 4(-2) = -1$$

B) $\text{Cr}_2\text{O}_7^{2-}$

$$\text{Cr}^{\text{+6}}$$

$$2(x) + 7(-2) = -2$$

C) $\text{ZnH}_2$

$$\text{Zn}^{\text{+2}}$$

$$x + 2(-1) = 0$$

4) Which solution has the same number of moles of NaOH as 50.00 mL of 0.100 M solution of NaOH? Circle one answer.

a) 20.00 mL of 0.200 M solution of NaOH

b) 25.00 mL of 0.175 M solution of NaOH

c) 30.00 mL of 0.145 M solution of NaOH

d) 50.00 mL of 0.125 M solution of NaOH

e) 100.00 mL of 0.0500 M solution of NaOH

$$0.100 \text{ M} \times 0.0500 \text{ L} = 0.00500 \text{ moles}$$

$$0.0500 \text{ M} \times 0.1000 \text{ L} = 0.00500 \text{ moles}$$
5) Write the balanced exchange reaction between potassium chloride and silver nitrate. Include all phases.

$$\text{KCl (aq)} + \text{AgNO}_3 (aq) \rightarrow \text{AgCl (s)} + \text{KNO}_3 (aq)$$

6) Label each statement as either True or False.

a) If the temperature of a gas is raised from 50 °C to 100 °C, the average kinetic energy will decrease.  
   _False_

b) If the volume of a gas is decreased from 2.0 L to 1.0 L and the temperature remains constant, the pressure will increase.  
   _True_

c) If the temperature of a gas is decreased from 150 °C to 100 °C, the root-mean-squared speed will stay the same.  
   _False_

d) According to the kinetic molecular theory of gases, pressure of the gas is caused by collisions of the gas molecules with the container.  
   _True_

e) According to the kinetic molecular theory of gases, at a given temperature all gas molecules with the same molecular weight will move at identical speeds.  
   _False_

7) Below is a plot of the molecular speeds of two ideal gases. One shows the molecular speeds for argon and the other for helium. Label each curve.
8) A mixture of 0.2 mol of N₂ (g) and 0.3 mol of Ar (g) are in a container of unknown volume. The pressure inside the container is 1.0 atm and the temperature is 0.0 °C. What is the volume of the container?

\[ V = \frac{nRT}{P} = \frac{(0.2 + 0.3) \text{ mol}}{1 \text{ atm}} \times 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times 273.15 \text{ K} \]

\[ = 11.21 \text{ L} \to 10 \text{ L} \]

Part II. Longer Problems (11 points each) (Answer 3 of 4)
Cross out the question that you skip.

9) Predict the products when the following reagents react. For full credit, balance each reaction label all phases, and indicate what type of reaction takes place.

a) Pb(CH₃COO)₂ (aq) + Na₂SO₄ (aq) → PbSO₄ (s) + 2NaCH₃COO (aq)

Type of Reaction: \underline{Precipitation} Reaction, Exchange (Metathesis) for partial credit

b) HClO₄ (aq) + KOH (aq) → H₂O (l) + KClO₄ (aq)

Type of Reaction: \underline{Acid-Base} Neutralization, Neutralization, Exchange for partial credit

c) HI (l) + H₂O (l) → H₃O⁺ (aq) + I⁻ (aq)

Type of Reaction: \underline{Strong Acid} Reaction
10) Balance the following Reduction-Oxidation Reaction in acidic conditions.
\[
Pb (s) + H_2SO_4 (aq) \rightarrow PbO (s) + SO_2 (g)
\]

**Oxidation**
\[
H_2O + Pb \rightarrow PbO + 2H^+ + 2e^-
\]

**Reduction**
\[
2H^+ + H_2SO_4 + 2e^- \rightarrow SO_2 + 2H_2O
\]

\[
Pb^{2+} + H_2SO_4 (aq) \rightarrow PbO (s) + SO_2 (g) + H_2O (l)
\]

11) When 1.0 mol of ethanol (C\textsubscript{2}H\textsubscript{6}O) is combusted with excess O\textsubscript{2} at 400°C and in a 10.0 liter container, what is the final pressure of each product, assuming all products are in the gas state?
\[
C_2H_6O (l) + 3 O_2 (g) \rightarrow 2CO_2 (g) + 3H_2O (g)
\]

1 mol C\textsubscript{2}H\textsubscript{6}O makes 2 moles of CO\textsubscript{2}, 3 moles H\textsubscript{2}O

\[
P_{CO_2} = \frac{n_{CO_2} \cdot R \cdot T}{V} = \frac{2.0 \text{ mol} \cdot 0.08206 \text{ L atm mol}^{-1} \cdot (400 + 273.15 \text{ K})}{10.00 \text{ L}} = 11.04 \text{ atm}
\]

\[
P_{H_2O} = \frac{n_{H_2O} \cdot R \cdot T}{V} = \frac{3.0 \text{ mol} \cdot 0.08206 \text{ L atm mol}^{-1} \cdot (400 + 273.15 \text{ K})}{10.00 \text{ L}} = 10.57 \text{ atm}
\]

12) To determine how much lead (Pb\textsuperscript{2+}) is in an unknown water sample, it is titrated to the equivalence point with a 0.010 M Na\textsubscript{2}SO\textsubscript{4} (aq) solution.

a. Write out the balance chemical reaction between lead nitrate and sodium sulfate.

\[
Pb (NO_3)_2 (aq) + Na_2SO_4 (aq) \rightarrow 2NaNO_3 (aq) + PbSO_4 (s)
\]

b. You find that it takes 4.1 mL of 0.010 M Na\textsubscript{2}SO\textsubscript{4} to reach the equivalence point for a 3.0 L water sample. What is the original concentration of the lead ions in the water?

\[
N_{Na_2SO_4} = 0.041 L \times 0.010 M \text{ Na}_2\text{SO}_4 = 0.00004 \text{ mol} = 4.1 \times 10^{-5} \text{ moles Na}_2\text{SO}_4
\]

\[
4.1 \times 10^{-5} \text{ moles Na}_2\text{SO}_4 \times \frac{1 \text{ mol Pb(NO}_3)_2}{1 \text{ mol Pb}^{2+}} \times \frac{1 \text{ mol Pb}^{2+}}{1 \text{ mol Na}_2\text{SO}_4} = 4.1 \times 10^{-5} \text{ moles Pb}^{2+}
\]

\[
M = \frac{4.1 \times 10^{-5} \text{ moles Pb}^{2+}}{3.0 \text{ L}} = 1.4 \times 10^{-5} \text{ M} \rightarrow 1.4 \times 10^{-5} \text{ M}
\]
Part III. Long Problems (16 points each) (answer 2 of 3) Cross out the question that you skip.

13) A. Based on the following information:

\[ \text{CaCO}_3 (s) \rightarrow \text{CaO (s) + CO}_2 (g) \quad \Delta H = 178.1 \text{ kJ} \]

\[ \text{CO}_2 \rightarrow \text{C} (s) + \text{O}_2 (g) \quad \Delta H = -393.5 \text{ kJ} \]

What is the enthalpy of the reaction?

\[ \Delta H_{\text{rxn}} = 178.1 + 393.5 = 571.6 \text{ kJ} \]

CaCO\textsubscript{3} (s) → CaO (s) + C (s, graphite) + O\textsubscript{2} (g). \quad \Delta H = 571.6 \text{ kJ.}

B. Based on your answer in part A, when 10.0 g of calcium carbonate decomposes into calcium oxide, graphite, and oxygen in a coffee cup calorimeter, what is the expected temperature change of the calorimeter assuming the specific heat of the calorimeter is 4.07 J/g°C and the mass of the calorimeter is 1000. g. Be sure to clearly indicate if the temperature increases or decreases.

\[ q_{\text{cal}} = mC_s\Delta T \]

\[ q_{\text{cal}} + q_{\text{rxn}} = 0 \]

\[ q_{\text{cal}} = -q_{\text{rxn}} \]

\[ -q_{\text{rxn}} = mC_s\Delta T \]

\[ q_{\text{rxn}} = \Delta H_{\text{rxn}} \cdot n_{\text{CaCO}_3} \]

\[ q_{\text{rxn}} = 571.6 \text{kJ} \cdot \frac{10.09 \text{gCaCO}_3}{100.08 \text{g/mol}} = 57.109 \text{kJ} \]

\[ -57.109 \text{kJ} \cdot \frac{1000.0}{1105} = m C_s \Delta T \]

\[ -57.109 \text{kJ} \cdot 1000.0 \cdot 4.07 \text{J/g°C} \cdot \Delta T \Rightarrow \Delta T = -14.8 \text{°C} \]

14) A 100.0 L container at 25 °C has a partial pressure of N\textsubscript{2} (g) of 0.50 atm and a partial pressure of O\textsubscript{2} (g) of 1.5 atm. After the following reaction takes places, what are the partial pressures of each of the molecules?

\[ 2 \text{N}_2 (g) + 5 \text{O}_2 (g) \rightarrow 2 \text{N}_2\text{O}_5 (g) \]

\[ n_{\text{N}_2} = \frac{5 \times 100.01}{0.08206 \cdot \text{L atm}} \cdot \frac{298.15}{\text{K}} = 2.04 \text{ mol N}_2 \]

\[ n_{\text{O}_2} = 3 \cdot n_{\text{N}_2} = 6.13 \text{ mol O}_2 \]

\[ \frac{2 \text{ mol N}_2}{2 \text{ mol N}_2} \cdot \frac{2 \text{ mol N}_2\text{O}_5}{2 \text{ mol N}_2} = 2.04 \text{ mol N}_2\text{O}_5 \]

\[ \frac{2 \text{ mol N}_2}{5 \text{ mol O}_2} = 2.45 \text{ mol N}_2\text{O}_5 \]

\[ 2 \text{N}_2 + 5 \text{O}_2 \rightarrow 2 \text{N}_2\text{O}_5 \text{(g)} \]

\[ P_{\text{N}_2} = 0.50 \text{ atm} \]

\[ P_{\text{O}_2} = 1.50 \text{ atm} \]

\[ P_{\text{N}_2\text{O}_5} = \frac{2.04 \text{ mol N}_2\text{O}_5}{5} \]

\[ P_{\text{O}_2} = \frac{1.02 \text{ atmL}}{0.08206 \cdot \text{L atm}} \cdot \frac{298.15}{\text{K}} = 0.25 \text{ atm} \]

\[ P_{\text{N}_2\text{O}_5} = 2.04 \text{ atm} \]
15) One of the chief concerns of using carbon-based fuels is the release of the greenhouse gas CO₂ into the atmosphere. It would be best to use a fuel that releases a lot of heat and the least amount of CO₂. Using enthalpy of combustion, determine which fuel, glucose (C₆H₁₂O₆) or octane (C₈H₁₈), has a higher heat of reaction per mole of CO₂ created.

Use the table below of enthalpy of formations and balanced combustion reactions to determine kJ/mole CO₂ for each fuel.

Glucose: \(-407.2\) kJ/mole CO₂

Octane: \(-886.7\) kJ/mole CO₂

<table>
<thead>
<tr>
<th>Molecule</th>
<th>(\Delta H^\circ) (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₆H₁₂O₆ (Glucose)</td>
<td>(-1273.02)</td>
</tr>
<tr>
<td>C₈H₁₈ (Octane)</td>
<td>(-226.61)</td>
</tr>
<tr>
<td>CO₂ (g)</td>
<td>(-393.5)</td>
</tr>
<tr>
<td>H₂O (l)</td>
<td>(-285.83)</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
C_6H_{12}O_6(g) + 6O_2(g) & \rightarrow 6CO_2(g) + 6H_2O(l) \\
\Delta H_{m,n} &= 6 \Delta H^\circ_{f, CO_2} + 6 \Delta H^\circ_{f, H_2O(l)} - \Delta H^\circ_{f, C_6H_{12}O_6} - 6 \Delta H^\circ_{f, O_2} \\
&= 6(-393.5) + 6(-285.83) - (-1273.02) - 0 \\
&= -2802.96\text{ kJ}
\end{align*}
\]

\[
\frac{\Delta H_{m,n}}{\text{mol CO}_2} = -2802.96\text{ kJ/mol CO}_2 \approx -407.16\text{ kJ/mol CO}_2
\]

\[
\text{Octane: } C_8H_{18} + \frac{25}{2}O_2 \rightarrow 8 CO_2(g) + 9 H_2O(l)
\]

\[
\begin{align*}
\Delta H_{m,n} &= 8 \Delta H^\circ_{f, CO_2} + 9 \Delta H^\circ_{f, H_2O} - \Delta H^\circ_{f, C_8H_{18}} - \frac{25}{2} \Delta H^\circ_{f, O_2} \\
&= 8(-393.5) + 9(-285.83) - (-226.61) - 0 \\
&= -5493.86\text{ kJ}
\end{align*}
\]

\[
\frac{\Delta H_{m,n}}{8\text{ mol CO}_2} = -5493.86\text{ kJ/8 mol CO}_2 = -886.7\text{ kJ/mol}
\]

Scores: Part I _______, Part II _______, Part III _______, Grade ______